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PRIFYSGOL BANGOR UNIVERSITY

Athlete monitoring in rugby union: inter- and intra-week associations of objective and subjective training markers with load during an entire Rugby Union Season.

By Davide Mondin

Thesis submitted to Bangor University in fulfilment of the requirements for the Degree of Masters by Research at the School of Sport, Health, and Exercise Sciences, Bangor University.

November 2020

DECLARATION

Yr wyf drwy hyn yn datgan mai canlyniad fy ymchwil fy hun yw'r thesis hwn, ac eithrio lle nodir yn wahanol. Caiff ffynonellau eraill eu cydnabod gan droednodiadau yn rhoi cyfeiriadau eglur. Nid yw sylwedd y gwaith hwn wedi cael ei dderbyn o'r blaen ar gyfer unrhyw radd, ac nid yw'n cael ei gyflwyno ar yr un pryd mewn ymgeisiaeth am unrhyw radd oni bai ei fod, fel y cytunwyd gan y Brifysgol, am gymwysterau deuol cymeradwy.

I hereby declare that this thesis is the results of my own investigations, except where otherwise stated. All other sources are acknowledged by bibliographic references. This work has not previously been accepted in substance for any degree and is not being concurrently submitted in candidature for any degree unless, as agreed by the University, for approved dual awards.

Contents

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This thesis is the realisation of a little dream in the field where I always lived before as athlete and secondly as strength and conditioning coach.

Writing this thesis has been particularly hard because I never stop working for elite level sport while I was writing and collecting the data for it but it gives to me new knowledge that helped me to look at my job in a modern and deeper way.

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THESIS ABSTRACT

During recent years sport has become more strenuous with increasing athletic demands from competition schedules and increased training. This trend makes the balance between training and recovery difficult, exposing the athlete to increased injury risk and underperformance. Regular athlete monitoring can be a key tool to help practitioners to quantify training looking at training response and the impact of possible underperformance allowing practitioners to modify and individualise training accordingly.

This thesis consists of three main chapters which include, a general introduction (Chapter 1), a literature review around the topic of athlete monitoring (Chapter 2), and a 1-year longitudinal experimental research study (Chapter 3).

Chapter 1 gives an introduction and rationale for monitoring athletes, indeed with the increased demands from sport and the physical evolution athletes it has become very important to find tools to monitor athlete training load response, and the recovery/work ratio attributed to every player, the second part of the chapter presents the current trends related to athlete monitoring.

The Chapter 2 describes and examines some of the tools adopted in current athlete monitoring practice including the main subjective and objective monitoring tests commonly used.

Chapter 3 presents a 1-year longitudinal research study examining the within-participant relationship between training load and athlete monitoring markers within a cohort of rugby union players.

CHAPTER 1: GENERAL INTRODUCTION

Over recent years team sport has become more strenuous given the increase in the number of competitions and their intensity. This has placed an increased demand on physical capacity and consequently has required an increase in both training volume and intensity. (Brooks, 2004). This has posed challenges to practitioners who are continually attempting to prescribe training to improve performance and reduce the risk of injury, whilst preventing overtraining by allowing sufficient recovery to allow adaptation to occur (Budgett, 1998). Over-reaching and overtraining can likely be attributed to errors in programming and periodisation combined with external factors including, work, life stress, and illness, which could interfere with a suitable recovery (Morton, 1997). Typical symptoms include, increased resting heart rate, lower level of testosterone and higher of cortisol, sleep disturbance and mood changes (Halson, 2002; Morgan, 1988). However significant reduction in aerobic capacity, decrease in hamstring strength and decrease in neuromuscular power (as for example a reduction in a jump test performance) (Coutts, 2007) could indicate early stages of overreaching (Cormack, 2008). To be able identify these body signs or to prevent these symptoms, it can be fundamental to avoid a non-functional overload or overtraining, which is not easy due to athletes' individual responses to a given training stimulus, and the training load required for adaptation. In addition, each athlete can have a biopsychosocial stressor external to training which may affect their ability to recover and can cause accumulated fatigue, enhancing injury risks (Mann, 2014)

Understanding and considering the individual response to a program can be very difficult, to prevent this type of issue, in the last few years, most practitioners have adopted athlete monitoring system (Taylor 2012). A monitoring system could shed light on an athlete's response to a determined session or block of training, allowing to the coach an individualised approach to ensure that the internal load experienced by the athlete corresponds with the coach expectations (Halson, 2014).

The benefits of scientific monitoring of athletes include explaining changes in performance, increasing the understanding of training responses, revealing training response and accompanying needs for recovery, informing the planning and modification of training programs and competition calendars, and, importantly, ensuring therapeutic levels of load to minimize the risk of non-functional overreaching, injury, and illness (Halson, 2014).

The main role of the strength and conditioning coach and support staff must be to prescribe optimal training programs that prevent both over and under training.

CHAPTER 2: LITERATURE REVIEW

Response to training process

Training can be defined as the utilisation of biological process to increase fitness and consequently improve performance (Brooks, 2004). A positive training adaptation is achieved through the prescription of an optimal balance between external load, tissue/metabolic capacity and adequate recovery (Drew, 2016). An adequate recovery following a training load, promotes tissues remodeling, restores homeostasis, and ultimately results in a higher level of fitness in the desired physical quality and improved performance (Soligard, 2016). A successful training stimulus must involve an overload able to cause functional overreaching characterised by a very short period of underperformance (Halson, 2004), that followed by an adequate rest period can bring a positive adaptation and consequently an improvement in performance, this stage of performance decrement can be defined as functional overreaching and it can last few days (Meeusen, 2013). However, if the rest period is not sufficient to recover from an excessive prolonged training load an abnormal training response can occur developing a state of non-functional overreaching (Meeusen, 2013). It can take to several weeks of performance decrement, prolonged fatigue and potentially to injury (Drew, 2016; Meeusen, 2013).

A very prolonged period of non-functional overreaching often results in signs of physiological and psychological distress (Halson, 2004), causing several months of before returning to normal performance capacity (Meeusen, 2013).

The first signs and symptoms of non-functional overreaching and overtraining can be prolonged performance decrement, with physiological signs as for example hormonal imbalance with decreased testosterone and increased cortisol levels (Corcoran, 2012), or altered heart rate manifested as a decrease exercise heart rate and an increase during resting periods (Jeukendrup, 1998).

Non-functional overreaching can also result in psychological disturbance for example increased fatigue and decreased vigor (Meeusen, 2013), showing very important symptoms like mood state deterioration that often precedes a drop in performance (Corcoran, 2012).

Athletes often show very similar symptoms between non-functional overreaching and overtraining making difficult distinguish between them, generally the symptoms of overtraining syndrome. Typical symptoms include subjective feelings of muscle soreness and fatigue, decline in performance capacity, and mood disturbances. Distinguishing between overreaching and overtraining is difficult and can only be based on differences in the time needed for performance restoration (Meeusen, 2013; Corcoran, 2012; Halson, 2004). For this reason, many have attempted to measure the magnitude and time-course of underperformance as an indicator of maladaptation. Fatigue is a complex phenomenon that has a variety of possible mechanisms. Indeed, a number of different definitions of fatigue exist (Halson, 2014), such as central fatigue, mental fatigue, muscle fatigue, peripheral fatigue, physical fatigue, and supraspinal fatigue. Common definitions of fatigue include ‘‘failure to maintain the required or expected force (or power output)’’ (Edwards, 1983) or an “inability to complete a task that was once achievable within a recent time frame’’ (Pyne, 2011). Therefore, encapsulating fatigue as a single entity is problematic (Enoka, 2016).

In the absence of definitive markers of fatigue researchers and practitioners have developed tests to quantify training load, measure functional capacity and subjective responses to training. Together these tests can in some instances highlight maladaptation. Using these tests can provide information for the recovery time prescribed following training (Borresen, 2009).

Many factors can influence fitness: age, sex, training history, psychological factors, initial training status, mode, intensity and training, recovery potential, exercise capacity, non-training related stress, stress tolerance and the individual’s genetics. The multitude of factors that can affect optimal adaptations is therefore vast and unique to each individual, and it make fundamental find a monitoring system able to give immediate feedback to the coach about the personal athlete responses to training from the proposed load.

Models of Athlete Monitoring

As previously outlined, fatigue is a complex and multifaced process, and no single marker of an athlete's response to load can predict maladaptation (Borresen, 2009). Furthermore, a gold standard method for monitoring does not exist, consequently in a practical setting, it is preferred to use a variety of measurement tools (Akenhead, 2016). For this reason, it is very important to adopt a multifactorial approach to monitoring the athlete during the training process (Meeuwisse, 2007). For this purpose, different monitoring test batteries that encapsulate the quantity an acute response to training alongside other tests of performance capacity and subjective response are needed in order to take action before that the underperformance can occur have been proposed (Thorpe, 2017)

Therefore, choosing the most appropriate test to be able to provide useful information to coaches and scientist displaying measurement characteristics of validity, reliability and sensitivity becomes crucial (Ryan, 2019). In terms of validity, it would appear that a maximal test is the most relevant way to measure underperformance. The diagnostic approaches to test the performance capacity within the literature include sprints, repeated sprints, jumps, maximal voluntary contractions and maximal oxygen consume (Thorpe, 2017) for example multiple jumps test (Twist, 2014), 1 repetition maximal test (Jovanović, 2014) or maximal oxygen uptake VO_{2max} test using an incremental maximal test (Coutts, 2007). Another monitoring approach that has been proposed in the literature has been the biochemical and blood training markers such as analysing testosterone, cortisol concentration and their ratio (Handziski, 2006). Indeed, an increase in creatine kinase is considered an indirect possible indicator of muscle damage and has been recommended as a useful measure to monitor a possible maladaptation, however these monitoring tools are time consuming, very expensive and invasive making regular testing difficult (Akenhead, 2016).

The literature suggests that monitoring for just one day per week is not sufficient for an athlete monitoring system (Esmaeili, 2018). Therefore, due to the high cumulative training load during a busy season and preseason training calendar it is important for practitioners to utilise monitoring tools that are rapid and non-invasive so that daily testing of athlete status without increasing the athletes perceived load. This consequently decreases the injury risk, and in this sense the repeated maximal performance efforts are likely to contribute to a fatiguing effect and interfere with the performance and training plan. So, the main objective of the practitioners is to find a fast and easy system to identify the relationship between training load and maladaptation.

Practitioners are conscious about the important role that a daily monitoring system can provide, describing important characteristics the economy of time consumed to test and the of the cost in terms of money invested to monitor (Starling, 2018) and summing up the perfect monitoring characteristic. In addition to being inexpensive and non-invasive, another important aspect of athlete monitoring is to be able to provide immediate feedback and be time efficient (completed in 5 to 10 minutes), (Starling, 2018).

Quantifying External Training Load

An important aspect of monitoring the training process is to quantify the work carried out by the athlete. The training load is the strain placed on an athlete, that can be manipulated in order to obtain the desired training response (Impellizzeri,2019). Training load can either be defined as internal training load or external training load; external load is the work done by the athlete, (Wallace, 2009), and internal load is the athlete’s acute response to the external stimulus (Bourdon, 2017; Borresen, 2009).

External load is the physical work prescribed in the training plan (Impellizzeri, 2019) and it is independent of the athlete’s psychophysiological characteristics, (Wallace, 2009), it consists of quantity and organisation of the training input (Impellizzeri, 2019). There are sports where monitoring external load is relatively easy as for example in cycling where it is possible to measure power output (Jobson, 2009). However, in team sport this type of monitoring can be difficult due to the variety of training input such as skills training, on feet conditioning and resistance training (Halson, 2014). Measuring external load in team sports includes measuring variables including, total distance run and speed (number of sprints at certain speed), jumps and collisions during rugby skills (Impellizzeri, 2004), tonnage, volume, and velocity generated during lifting in resistance training (Hiscock, 2015). The recent development of more sophisticated technologies now allows the estimation of external load even in complex situation like team sports (Cardinale, 2017). Utilizing technology such as Global Positioning Systems (GPS) (Coutts, 2008), gyroscope or Time Motion Analysis (TMA), allows the determination of metrics such as distance covered, velocity, direction of movement and number of collisions, (Dwyer, 2012). Nevertheless, these technological advances pose other problems, in that many cannot be used across all training modalities. Meaning that practitioners do not have a uniform measure across the training process.

In addition, in team sport, even when the same external load is prescribed to the whole team, specific modifiable and nonmodifiable factors such as training status, nutrition, health, psychological status, and genetics may result in individual athlete’s response interfering with the adaptive process (Vellers, 2018). In turn, this will cause individual athletes to feel a different internal load (Impellizzeri, 2019), for example the same external load can be cause different and individual perceived exertion during the same session (Foster, 2001), or different percentage of maximal oxygen uptake (Vollaard, 2009). Due to this difference in internal response to external training load it is fundamental to find valid and reliable measures of internal training load, estimating which is the stimulus for training able to induce adaptations (Impellizzeri, 2004).

The use of both subjective and objective markers of training can give a whole picture of the athlete assisting the coach and support staff to make evidence-based decision on the players' training load (Purge, 2006).

Quantifying Internal Training Load

As described previously many measures of external and internal training loads are problematic in practical settings. Although they have the ability to provide detailed data, these devices face many limitations such as expensive in terms of cost and time consumed to collect and analyse the data. By far the most practical and adopted method of quantifying internal training load is the modified use of ratings of perceived exertion (RPE).

The modified session rating of perceived exertion (sRPE) method takes into consideration both the intensity and the duration of the training session (or competition) to calculate the internal training load (TL). The athlete provides a rating effort during that specific session (Haddad, 2017) on a scale of 1-10 following the verbal anchors proposed by (Foster, 2001) where 1 correspond to rest and 10 to maximal effort. A single arbitrary unit (AU) representing the magnitude of global TL for each session is then calculated by the multiplication of perceived effort for the session and the duration of the training session [TL = RPE x session duration (min); Haddad, 2017]. The session RPE has been found to be a valid monitoring tool to measure the internal training load (Impellizzeri, 2004). The strength of this approach is based on its potential to integrate different types of stimuli (Foster et al., 2001) and it has been shown to be correlated to heart rate responses (Manzi,2010; Impellizzeri, 2004) also during a season long period (Kelly, 2016) and to external loads measured by accelerometers (Scanlan, 2014). To better describe the session load is important to minimize the influence of the last effort executed, consequently it is important collect athlete's session-RPE 30 minutes after each training session to ensure that the perceived effort is referred to the whole session rather than the most recent exercise intensity (Impellizzeri,2004).

Session-RPE method has been used as useful tool to measure the internal training load during training cycles of different type of sports as for example in soccer (Impellizzeri, 2004), in swimming (Wallace, 2009), in basketball (Manzi, 2010) and in rugby (Scott, 2013). Research has shown that session RPE is able to give a useful measure of the training TL across different type of stimulus, providing a valuable tool to investigate the relationship between training-load and athlete response (Chamari, 2012; 2013). Furthermore, quantifying the training load demands during indoor training sessions has often been a limitation of GPS-based systems due to several signal limitations (Malone, 2017). In sports like rugby there are several game phases like tackle, static phases and scrums that can cause muscle damages and are for sure a key part of the total load of a training session or a game however it is difficult to quantify using heart rate monitors, GPS or other devices (Elloumi, 2012) while session RPE has demonstrated a correlation between number of impacts in rugby training and its score (r = 0.55) (Lovell, 2013) underlining it to be an effective tool to measure training load even in complex sport like rugby.

Potential Objective and Subjective Measures of Training Load Response

As mentioned, to identify a single marker that would determine the athlete's response to training in rugby players is very difficult because they are exposed to a high amount of contact, sprint and change of directions (Tavares, 2017). Indeed, there is a need to determine the magnitude of player response via measures of workload, objective response of training load (Physiological, biochemical and subjective response (e.g. muscle damage or soreness), to assess recovery and readiness for training or competition (Quarrie, 2017), this requires a suitable battery of tests that enables sport scientists to make informed decisions on each player's health status.

In a recent publication with rugby sevens players, the researchers tried to verify whether a short item questionnaire consisting of eight questions and maximal performance tests were able to show significant changes during a six week of progressive load training program and concomitantly if the session RPE was able to describe different load during different training period. The total load of RPE and the total score obtained from the 8-item questionnaire increased during the intense period of training and decreased during a reduced training load period. Simultaneously, physical performances decreased during the intense training period of training. The changes in total RPE were significantly correlated over the training period (r=0.63-0.83) (Elloumi, 2012). The main limitation of this paper has been proposing maximal effort test that are not possible to administer daily as they add to the training load. Furthermore, the author (Elloumi, 2012) did not try to correlate the single question of the 8-item questionnaires to the training load, making impossible to know which of the question was related to change in training load. Another paper including both objective and subjective marker of training markers has been proposed by Ryan, (2020) that monitored 42 Australian football players during an entire competitive season (the data have been collected only during the in-season period without considering pre and off season periods) through a wellness questionnaires (48,72 and 96 h post-match) and muscle soreness score, a countermovement jump and an eccentric hamstring test that were used only once a week (72 h post-match),their findings showed that CMJ test, eccentric hamstring force, and perceptual wellness test all possessed acceptable sensitivity. However, this study did not relate these monitoring data against outcome measures (injury or performance or training load), consequently without describing what type of training load change these tests were related to.

Another study that investigated on the responses of different perceptual and neuromuscular measures to overall training load on professional rugby players has analyzed the data from the first 7 days during a non-competitive period. Measures of perceptual wellness and muscle soreness were collected every day and neuromuscular readiness was measure by a jump performance on days 1, 2, 3, 4, and 7 after the game, in this study the effect of training load on the increase in muscle soreness and decrease in neuromuscular performance was evident (Tavares, 2018).

All these papers are showed that both objective and subjective markers of training can potentially be used by coaches and scientists to identify meaningful changes in athlete response but their main limitations are the short periods considered or a missing correlation with training load. Furthermore, many of these papers, especially who considered a shorter period, used performance tests impossible to use daily and consequently showing a weak data consistency. Indeed, a plethora of tests exist to assess training response, those selected must be valid, reliable, and practically convenient in the applied setting (Twist, 2014).

Objective Training Markers

Performance is considered to be the best objective indicator of physical and physiological response to training (Currell, 2008), even if effective in this sense,VO_{2max} test can be expensive and very time consuming especially for a team sport ,an alternative can be the maximal shuttle running to exhaustion that showed reduced speed by ~5% and ~10% at weeks 5 and 6, during a 6-week intensified training period rugby league players (Coutts, 2007) and demonstrating to be a sensitive monitoring tools. However, maximal-performance tests can cause additional training load on athletes making them impossible to use often during the season (Nédéle, 2012).

Many objective monitoring tools, that do not impact on the player load have been suggested including, various biochemical (Gabriel, 1992), in particular markers of muscle damage, hormonal and immune measures have shown to respond to changes in training load and have been associated with maladaptation in numerous athletes (Coutts, 2007; Halson, 2002). For example, salivary measures of cortisol demonstrated a positive relationship between session RPE and salivary cortisol, (between $r = 0.36$ and 0.38, $p < 0.05$; Rudolph, 1998), also the salivary testosterone to cortisol ratio demonstrated intraweek variation based on athlete overreaching in rugby union (Gaviglio, 2014). Despite these findings these biomarkers are often inconsistent due to factors such as the influence of circadian rhythms, nutrition and hydration status and psychosocial factors, (Hug, 2003). Furthermore, due to drawing blood or obtaining saliva samples from athletes, may present logistical issues as high costs and time needed for analysis, making these measures impractical for daily monitoring (Twist, 2014), additionally biomarkers in rugby players showed high individual variability and poor temporal relationship and were not correlated with neuromuscular tests (Twist, 2012). Rugby union involves many activities that require an optimal neuromuscular capacity and performance (Crewther, 2009) and require at least one test in a daily test monitoring system that would be able to test the neuromuscular responses. For this purpose, has been proposed the maximal 10 m sprint, which can be tested using timing gates which have been shown to provide reliable data over short (10–30 m) distances (CV = 1.0–1.5%) However, this method is time consuming, expensive and would add load to the normal rugby training activity. Furthermore, the necessity of highly standardised conditions from one test to another make it very difficult to be used often during the season. (Meeusen,2013). This means that there are the needs of alternative test to prevent a possible performance decrement (Meeusen, 2013). In terms of neuromuscular overload, it has been noted that an accumulation of it can affect movement efficacy of the jump (Cormack, 2013). For this reason, the vertical jump has been used from a multitude of studies to calculate the time course of recovery from fatiguing training or competition in sport involving high neuromuscular efforts (Taylor, 2012). Two vertical jumps that are widely used to regularly monitor athletes are the countermovement jump (CMJ) and squat jump (SJ), A countermovement jump is where the jumper starts from an upright standing position, makes a preliminary downward movement by flexing at the knees and hips, then immediately extends the knees and hips again to jump vertically up off the ground , while during the SJ, the athlete descends into a semi-squat position (90° knee angle) and holds this position for approximately 3 seconds before takeoff. Countermovement jump is able to reflect an effective utilisation of the stretch-shortening cycle, where the muscles are ‘pre-stretched’ before shortening in the desired direction. Therefore, it is able to show a well-developed capability to co-activate muscles (Hooren, 2009), it has been hypnotized that the difference between the CMJ and SJ would be suggestive of a better capability to store and use elastic energy (Komi,1978).

The CMJ has been shown to be responsive to match load, with substantial reductions in CMJ flight time following Australian football matches (Cormack, 2008) and correlated with an increase in low-speed movement and reduced accelerations during Australian football matches (Cormack, 2013) furthermore, it showed high intraday and interday reliability and sensible changes in neuro-muscular function at 0, 24, and 72 hours followed a fatiguing high-intensity intermittent-exercise running protocol (Gathercole, 2015), this has been confirmed even in a practical setting with rugby players where it showed a significant decrease correlated to an intense neuromuscular effort until 4 days after a rugby game before to return to the resting CMJ test results (Mcclean, 2010), it has been used to count how many days rugby league players needed to fully recover from games based on how many days they take to return to their baseline levels, indeed the high practicality and low physiological strain of a CMJ test allows repeated measure of multiple individuals over a short period of time making this test easy to repeat during a team sport season giving multiple feedback during the week (Gathercole, 2015). A great attention has been focusing also on jump landing indeed the assess of it and the knee, hips and ankle biomechanics during landing would therefore be important for athletic screening and evaluation, however current video methods to assess landing biomechanics require time and expensive instruments (Petushek, 2012), although the biomechanics analysis of jumping landing is complex to propose as monitoring tool. The weight bearing lunge test (WBLT) has been associated with jump-landing, indeed greater passive open chain dorsiflexion ROM has been associated with greater hip and knee flexion and ability to perform a safe and efficient jump-landing (Fong, 2011), furthermore is result has been also associated with greater knee (r 0.28–0.49) and hip (r 0.28–0.30) displacement during a drop-landing task and consequently to a possible deficit of knee and hip flexion on a sagittal plan (Bell-Jenje, 2016) therefore, a good dorsiflexion range of motion can influence function of proximal structures in the lower extremity (Fong, 2011). WBLT test has demonstrated to be a valid test able to measure range of ankle dorsiflexion (Sman, 2014), it has been found to be a functional and reliable method to assess dorsiflexion showing an intra-rater intraclass correlation (ICC) ranged between 0.97 to 0.98 and the Inter-rater ICC ranged between 0.97 and 0.99. (Bennell, 1998). It consists of facing a wall with the involved foot in front, with great toe close to the wall while the uninvolved foot was placed comfortably behind the involved foot. The WBLT uses a knee-to-wall principle that requires the participant to perform a lunge in which the knee flexes to a point where the anterior knee go as close as possible to the wall while the test heel remains firmly planted on the floor (Hoch 2015) an iPhone is placed on the upper shin of the athlete and the goniometer app it is possible to obtain a precise angle of ankle dorsiflexion (Balsalobre-Fernández 2019).WBLT is able to explain more than 20% of the variance in maximum dorsiflexion and ankle displacement (Hoch,2015) that is one of the most common injuries in athletes especially in sports requiring change multiple change of direction is ankle injury (Doherty, 2014), and decreases in dorsiflexion is recognized as one of the main cause of this type of as a consequence of calf tightness (You, 2009).

Figure 1.1 Weight Bearing lunge test to measure the ankle dorsiflexion through the Iphone goniometer app.

Another of the most common injury in sport requiring change of direction is hip and groin , especially those that require change of directions and kicking (Machotka, 2009), indeed this this type of movements while running place a strain on fascial and musculoskeletal structures that may result in damage to the groin area (Falvey, 2009), consequently causing a reduction in hip adductor strength, that could possibly highlight a starting phase of underperformance or even take to specific area injuries (Whittaker, 2015).

This panoramic on hip and groin injuries suggest the need to measure the hip adductor strength and the adductor squeeze test is s a cheap and effective test (Malliaras, 2009), that showed high reliability and validity as clinical strength tests for adductor related groin pain (Martin, 2010), it consist on positioning the subject in a supine position on the floor, with hip flexion at 45° and knee flexion at 90°, place an inflated a commercially available sphygmomanometer in between his flexed knee, asking him to adduct maximally both knees and squeezing the cuff for at least 3 seconds , the pressure on the cuff will give a millimeters of mercury (mmHg), and the highest pressure value will be recorded giving a reliable and valid measure of the hip adductor strength (Delahunt, 2011) with 45° showing the highest squeeze values (Delahunt, 2011).

Being such a cheap and easy to administer test has been widely used as a marker of recovery to inform training prescription to help reduce the risk of load accumulation and of groin injuries (Roe, 2016), for example it has been shown that an AFL match can induce an 18% decrease in adductor squeeze scores, and players' adductor squeeze scores did not recover to baseline levels until 4- day post-match. These results indicated that adductor squeeze strength scores may be used as an objective marker of adductor strength, which can highlight players who may not have fully recovered from an AFL match (Buchheit, 2017) and base on these results possible adaptation and personalization of the general training program, reducing injury risks and managing the athlete load and performance. The adductor squeeze test has been used in many team sports as for example Rugby Union (Coughlan, 2014), Australian Rules (Crow, 2010), and Gaelic games (Delahunt, 2017), it's strength is the use of a very common, cheap and simple tool to value the strength status of a very sensible muscle department for sports requiring numerous change of directions and running phases, the same principle has been adopted from Mondin,2018 that has proposed a test for measuring proxy hamstring strength, the reason is that hamstring strains are one of the most frequent non-contact injuries in sport, especially in those that involve repetitive bouts of maximal sprinting (Schache, 2011), modifiable risk factors of hamstring injury include, lack of hamstring strength, hamstring overload, strength asymmetries between quadricep and hamstring, and between left and right legs (Croisier, 2002; McCall, 2014, 2015). Consequently, hamstring strength should be screened regularly in team sport athletes to identify those at an increased risk of hamstring injury (Schache, 2011), mostly of the possible hamstring screening strength tests are presenting injury risks, are time consuming and expensive (Mondin, 2018), a potential solution to monitor hamstring strength without injury risks or adding load to the athletes training can be the use of an isometric test (McCall, 2015).

Despite associations between isokinetic measures and hamstring strength at 30° and 90° and quadricep strength at 90° of knee flexion, the sphygmomanometer test was not applicable to assess quadricep strength at 30° of knee flexion. The sphygmomanometer tests were also shown to be reliable as shown during two separate assessment visits on a practical setting with professional rugby players (Mondin, 2018).

Mondin (2018), investigated the validity of an adapted sphygmomanometer test to assess hamstring and quadricep strength making a comparison with an isokinetic dynamometry considered the gold standard for hamstring and quadriceps strength profile (Harding, 2017). The adapted sphygmomanometer test measured the maximal isometric strength of the quadriceps and hamstrings at 30° and 90° of knee flexion, with strength expressed in millimeters of mercury (mmHg) via the sphygmomanometer scale, the main findings from this study were that adapted the sphygmomanometer test was valid in measuring hamstring at 30° (right, r = 0.329, 95% CI = 0.062–0.846, $p < 0.05$; left, r = 0.387, 95% CI = 0.138 –0.867, $p < 0.05$) and 90 flexion (Hamstring: right, r = 0.545, 95% CI = 0.342–0.912, $p < 0.01$; left, r = 0.643, 95% CI = 0.473 –0.935, $p < 0.001$) degrees of knee flexion and quadricep (Quadricep: right, r = 0.386, 95% CI = 0.136 –0.866, $p < 0.05$; left, r = 0.431, 95% CI = 0.193 –0.880, $p < 0.05$) at 90 ° of knee flexion compared to measures of isokinetic concentric strength at 60° s^1 (Mondin, 2018). So, this sphygmomanometer isometric strength sphygmomanometer test can be used to obtain valid and reliable measures of quadricep and particularly hamstring strength in the absence of costly laboratory equipment, using an adapted suggesting that this novel test could be routinely used to assess changes in hamstring and quadricep strength in athletes. The advantage of this test is that the equipment is relatively inexpensive, the method is easy to administer, and measures are recorded rapidly, and therefore could form part of a routine athlete monitoring or screening program. Indeed, measures could be made immediately after or during a recovery period from even high intensity training. As the sphygmomanometer test requires only few minutes to test hamstring and quadriceps strength making it a useful test for potentially monitoring athlete strength changes during the training week. However, it would be necessary in the future discover what type of asymmetries or Hamstring/quadricep ratio using this test could express an injury risk, due to these types of data did not show any correlation with the isokinetic dynamometer (Mondin, 2018)

Subjective Training Markers

Subjective markers of perceived ratings of wellness represent an increasingly popular, cheap and non-invasiveness (Main, 2009), method to assess athlete dose-response relationship to training load in athletes during intensive physical training (Thorpe, 2016; Raglin, 2001).

There are several well-established tools for sport specific psychometric questionnaires to assess how an athlete is coping with training and training load, these include the Profile of Mood States (POMS), the Recovery-Stress Questionnaire for athletes (REST-Q- Sport), Daily Analysis of Life Demands for Athletes (DALDA), and the Total Recovery Scale (TQR) (Halson, 2014). However while questionnaires can provide simple and often useful subjective information, factors such as frequency of administration, time taken to complete the questions, sensitivity of questionnaire, type of response required, time of day of completion and the amount of time required for appropriate feedback should all be considered (Halson, 2014) and this often result in consider this method as too lengthy to foster compliance with athletes (Twist, 2012), to limit this type of problem and increase the athlete's compliance the majority (80%) of sport science and strength and conditioning practitioners prefer to use a custom designed form, usually consisting of 4-12 items measured on a 1-5 or 1-10 point Likert scale (Taylor, 2012).

Over the course of a training week, it was found that perceptions of pain/soreness were highest 1 day post a game and decreased through the week to game day ($p < 0.001$). Furthermore, there was a significant improvement in ratings of wellness after a single week of reduced physical load, in which there was no game and reduced training (Twist, 2012). Subjective perceived muscle soreness and overreaching measurements taken have been demonstrated to be sensitive to underperformance during each training rugby training week, with subtle changes in training load eliciting changes in the player's perception of muscle soreness and general fatigue. Additionally, these results suggest that small changes to relative in-season training load, within professional rugby players, may have a significant impact on perceived training load (McClean, 2010), it is demonstrated also to be sensitive to daily fluctuations in training in team sport as for example elite soccer (Thorpe, 2016) and Australian Rules Football (Buchheit, 2013). It has been noted that after a rugby match the neuromuscular performance (tested with a CMJ test) take 48 hours' to be considered fully recovered while perceived overload and muscle soreness were still present. The prolonged increase in muscle soreness in rugby players post-game could have implications on training despite their neuromuscular performance has improved, the soreness feeling can indicate insufficient recovery compromising high intensity training (Twist, 2012). These findings suggest that such measures show particular promise as acute, simple, noninvasive assessments of training responses in elite team-sport athletes. (Thorpe, 2016). Furthermore this subjective ratings of wellness and soreness have demonstrated to be very sensitive to within-week training manipulations in elite Australian Football League players (Gastin, 2013) and for this reason it can potentially be used as a measure to understand when an athlete Is fully recover after a match, for example Thorpe

2016 has showed a progressive improvement of muscle soreness score after 1,2,4 days a football match with the respective value of 3.6 ± 0.6, 4.3 ± 0.7, 4.4 ± 0.7 on a 1-7 Likert scale where 7 means fully recovered and absence of muscle soreness, showing also a mean muscle soreness value of 5.1 ± 0.8 the pre-match day. So, monitoring muscle soreness from specific body sites seems to provide important information for coaches, and may provide further information that could help elucidate the training responses and/or recovery of their athletes (Tavares, 2018). Dividing the muscle soreness in different body sites is increasing the number of question, to keep the question on 4-12 items as proposed to safeguard the athletes' compliance, it could be a possibility use only muscle soreness on adapted perceived fatigue questionnaires, furthermore perceived stress and perceived soreness demonstrated to be the most responsive to training stressors of the 5 wellness elements examined in Ryan (2019) study, he demonstrated that these 2 elements showed to be still decreased at 96 hours post-match, and probably including sensitiveness to previous week's match, this theory has been confirmed from Mcclean, 2010 where the return to baseline values in general muscle soreness during the 5 d microcycle was accelerated compared the 7 and 9 d micro-cycles were the training load was higher . This rapid recovery occurred despite the same training being completed on day 1 post-match in all three experimental weeks. This suggests that optimal recovery of perception of general muscle soreness following a match is affected by many variables such as adaptation to previous training, the extent of damage that occurred during match play and is not limited to the type and amount of training completed in the days following competition.

Research aim

While much attention has been focused on the effect of rugby match-play on underperformance, less is known about how rugby training affects an athlete's response and readiness during a training week in highly-trained, professional Rugby players (Lindsay, 2015). Furthermore, as has been reported before it is difficult to describe the rugby player response to training with only one test as he can compromise his performance through different aspects of overload. For this reason to detect a sign of undeperformance and prevent a possible future state of chronic maladaptation it is necessary find a test battery that could describe athlete's training response and health status over time (Tavares, 2017), this could allow to prescribe individualized programs ensuring the correct balance between training load and recovery (Buchheit, 2013) avoiding overload over long period that could lead to overtraining or injury risks (Thorpe, 2016) ensuring sufficient recovery, and optimizing training adaptations (Tiernan, 2019),

Recent research has proposed that different monitoring test batteries that consider both psychological and physiological state of the player can help practitioners to confirm the effect of training programs to avoid overtraining or undertraining (Thorpe, 2017). In the current setting for this study (Rugbi Gogledd Cymru, RGC) a rigorous monitoring system has been utlised over the last 3 years without a clear indication of whether measures within this battery are useful to inform practitioner decision making. This problem is commonplace within sporting settings and there is a need for research to provide answers to these problems.

Therefore, the aim of this study was to assess the relationship between training load (measured via session RPE) and the athlete response to training measured via a battery of monitoring tests over the whole pre-season and in-season period. The athlete monitoring markers included both subjective and objective markers including, muscle soreness related to specific body parts, CMJ, adductor squeeze test, hamstring isometric strength test and WBLT. A unique approach of this study was to assess the relationship between markers and training load both between and within training week in order to inform practitioners of the best time to monitor during the week.

Another novel aspect of this study was the use of within-participant correlation (repeated measures correlation). Within-participant correlations offer a higher level of statistical precision than calculating correlations for individual players, or pooling player data by utilising the correct degrees of freedom. Correlational analyses between training load and monitoring tools methods has been calculated mainly by pooling data over time points, or by calculating Pearson's correlation coefficients separately for individual participants. Such approaches lead to a lower level of statistical precision and/or the problem of "pseudoreplication" in data analysis.

CHAPTER 3:

Athlete monitoring in rugby union: inter- and intra-week associations of objective and subjective markers with training load during an entire Rugby Union Season.

Abstract

Suitable athlete monitoring tests enable practitioners to make informed decisions when prescribing training. The aim of this study was to investigate the within-participant correlation between athlete monitoring markers and training load in professional rugby union both between and within training weeks. Twenty-one professional male rugby union players completed daily monitoring before every training, three times per week across pre-season and in-season periods (45 weeks). Markers included, ratings of muscle soreness (upper body, hamstring, quadriceps, glutes, calves), CMJ, adductor squeeze test, left and right hamstring isometric strength test and left and right WBLT. Internal training load was measured across all training sessions and matches using the rating of perceived exertion (sRPE). A within-participant correlation was used to examine the relationship between Monday markers and previous week training load; Tuesday markers and previous day training load and Thursday markers and current week training load. The results found that Monday hamstring isometric strength test for both right (r= -0.115;95% CI -0.22 -0.01; *p*=0.039) (Fig. 6.1) and left legs (r= -0.116, 95% CI -0.22-0.01; *p*= 0.036) significantly decrease, likewise muscle soreness score (on the Likert scale used in this study: 1-10 where 10 is no pain at all and 1 is unbearable amount of pain) decrease on Upper Body (r= -0.344; 95%CI-0.44 -0.24; *p*=<0.001), Quadriceps(r= -0.344; 95%CI -0.44 -0.24; *p*=<0.001), Hamstrings (r= -0.328; 95%CI-0.42 -0.23; *p*=<0.001), Glutes (r= -0.332; 95%CI-0.43 0.2; *p*=<0.001) and calf (r= -0.273; 95%CI -0.37-0.17; *p*=<0.001) showing a correlation between load accumulation and subjective and objective training markers. Only ratings of muscle soreness were related to training load within the same training week Quadriceps(r= -0.339; 95%CI-0.43 -0.24; *p*=<0.001), Hamstrings (r=-0.309; 95%CI -0.40 -0.21; *p*=<0.001), Glutes(r= -0.40; 95%CI-0.21 -0.310; *p*=<0.001) Calf (r= -0,207; 95%CI-0,30 -

0,10; *p*=<0.001) and at the end of the training week Upper Body(r=-0.117; 95%CI-0.22 -0.01; *p*=<0.001), Quadriceps (r= -0.177; 95%CI -0.28 -0.07; *p*=<0.001), Hamstrings (r= -0.220; 95%CI -0.32 -0.12; *p*=<0.001), Glutes (r= -0.247;95%CI 0.34 -0.14; *p*=<0.001), Calf (r= -0.137;95%CI=-0.24 -0.03; *p*=<0.001).These results suggest that perceived muscle soreness and isometric hamstring strength test are two useful tests to monitor athlete response to different training load, additionally it seems that muscle soreness is the only test able to respond to acute changes in load within the same week.

Introduction

Rugby union is a sport which requires both high intensity action (sprints, tackling, static holds, scrums, rucks and mauls) (Austin, 2011), involving a high amount of contact and leading to numerous muscle damage post training and competition causing alterations in neuromuscular performance and perceptual fatigue for up to 4 days post-match (McLean, 2010). The busy calendar and training plan mean less time for recovery days causing a period of underperformance (Coutts, 2007; Johnston, 2013). For these reasons to detect first signs of maladaptation through a test battery (Tavares, 2017), would allow to individualise the training programs ensuring the correct balance between training load and recovery (Buchheit, 2013) avoiding underperformance, overtraining or injury risks (Thorpe, 2016)

While much attention has been focused on the effect of Rugby match-play on athlete’s response, less is known about how Rugby training affects an athlete’s maladaptation and readiness during a training week in highly-trained, professional Rugby players (Lindsay, 2015).

It is important for practitioners to find monitoring tools that would be able to daily test athlete readiness and overreaching without increasing the athletes perceived load (Gabbett, 2017), the use of objective and subjective monitoring markers may assist the coach and support staff to make informed decisions (Hogarth, 2015).

Of the potential markers that could be utilized in a team sport environment the adductor squeeze test has shown promise (Tiernan 2019). Adductor squeeze strength as related to training load both within and between training weeks. Additionally, it was found a negative relationship between muscles soreness and adductor squeeze strength scores.

Muscle soreness is also a potential subjective marker of athlete response (Ryan, 2019), it has been shown to be related to decreases in performance in rugby athletes (McLean, 2010; Twist, 2014), and seperating muscle soreness to specific body sites seems increase its sensitivity to changes in training load (Tavares, 2018) showing within-week fluctuations in training load (Thorpe, 2016).

Another common is the countermovement jump (CMJ) (Webb, 2013) its results have been associated with muscle soreness and neuromuscular training response (Clarkson, 1995), showing signs of underperformance in the days following competition in collision-sport athletes (West, 2014) underling its possible use as useful tool to monitor athletes during the training process. this test has been suggested on daily monitoring routine by Howe (2015).

Another non-invasive test of athlete capacity was suggested by Mondin (2018) proposed a rapid and non-invasive proxy measure of hamstring and quadricep strength at 30^0 and 90^0 of knee flexion using an adapted sphygmomanometer, demonstrating its validity when compared with the gold standard (isokinetic dynamometer) and its reliability in a practical setting with professional rugby players during the preseason period, it would be worthwhile to investigate whether the adapted sphygmomanometer test could identify decrements in muscle strength during the training process caused by training or competition.

To our knowledge there is an absence of research examining if an objective and subjective monitoring test battery would be associated with acute change in training load, and especially there are no research that have considered a whole season verifying if this monitoring method can be useful to recognise first signs of overreaching. To demonstrate this kind of relationship it is necessary a novel statistical approach that would reduce the possibility "pseudoreplication" in data analysis offering a higher level of statistical precision.

Therefore, the aim of this study was to examine the association between monitoring tools and training load measured using the session RPE (total load, TL) both between and within training weeks in a professional rugby team during the entire pre-season and in season period.

To achieve this testing days took place before training on Monday, Tuesday and Thursday mornings of each week for 45 weeks so that weekly analysis could be performed. Each testing day consisted specifically of measures including: muscle soreness, CMJ, squeeze test, hamstring isometric strength test, WBLT.

We hypothesised that all muscle soreness scores of Monday morning for hamstring, quadriceps, calves glute and upper body , CMJ, squeeze test , hamstring isometric strength test and weight bearing lunge test presented a significant correlation when compared with the total load of the previous week, the second hypothesis is that the same test scores obtained on Tuesday morning would show a significant correlation when compared with Monday total load, as last hypothesis we expect a significant correlation between Thursday's test scores and the total load of the same week. Consequently, these tests are sensitive to changes in training load, showing a decrease in test scores with increasing training load, meaning that the tests may be suitable to identify possible training maladaptation in rugby players during the whole season.

Methods

Participants

Respectively 24 players during the preseason and 27 during the in-season agreed to take part in the study. All participants were male and members of the Rygbi Gogledd Cymru (RGC) regional rugby team who participate in the Welsh Premiership competition (age 24 ± 3 years; mass 99.74

± 29.86 kg). All players were contracted as full-time players and trained full time. Training was typically 3 days a week, with multiple sessions a day. Sessions included rugby pitch-based sessions (e.g., skills, conditioned games), gym/resistance sessions, conditioning sessions, recovery sessions (e.g. yoga and hydrotherapy) and matches. The typical training day was composed by 30 minutes of warming up and monitoring, 30 minutes of a specific work that could consist on prehab exercises, speed training or yoga session,1hour gym, 30 minutes rest,1hour skills,1 hour rest, 30 minutes of video analysis and 1 hour and half of rugby training .

All subjects provided written informed consent and ethical approval was granted by the School of Sport, Health and Exercise Sciences Research Ethics Committee at Bangor University.

Experimental approach

Data collection was carried out across a 45-week rugby season (2018-2019) including an 8-week preseason training period, and a 37week competitive season (from the 2nd July 2018- 7th May 2019). During this time period, and at the beginning of each training day (Monday, Tuesday and Thursday) both objective and subjective test scores were recorded before the first training session on an ipad linked via a google drive spreadsheet. The players inputted the data into the Ipad, which was immediately sent to a database and subsequently checked by the head S&C coach and researcher, to ensure that data were inputted correctly. Before any measurement was taken, the players participated in an activation session where they performed exercises over and under hurdles forwards, backwards and on each side, sliding leg glute activation and standing back relaxation stretches. Once the light warm-up and activation session was completed, the players measured their own body weight and other routine monitoring measurements on an iPad app. All measurement sessions were supervised, monitored and observed by the same strength and conditioning coaches, they started every morning answering to perceived muscle soreness scores (Upper body, hamstring, quadriceps, glutes, calves) and then they continued the measurements with the following order: counter movement jump height (CMJ), adductor squeeze strength, hamstring isometric strength test using a modified test previously reported (Mondin et al, 2018) and Weight Bearing Lunge Test (WBLT) through an iPhone placed on the upper shin of the athlete and using the goniometer app obtaining a precise data of ankle dorsiflexion (Balsalobre-Fernández 2019). Ratings of perceived exertion (RPE) were taken from each player within 30 minutes of each session, and training load was calculated for each session as a session rating of perceived exertion (sRPE) from the product of session RPE score and the duration of the session in minutes. Individual player timings for each session were recorded by the head S&C coach. All players were familiar with monitoring protocols from previous experience at the club (2-3 years). All testing took place in the training facilities of the club to ensure minimal disruption to the players' normal training schedule. The researcher was present at every training session and supervised all data collection to ensure that players performed the tests correctly.

Training Load

RPE was recorded 30 minutes (Tavares, 2018) after every training session or match to individualise the training load for every training session, to calculate the training intensity it has been used the Borg's 0–10 scale (Tiernan, 2019). RPE has been found to be a valid and reliable monitoring marker to measure the training load (Impellizzeri, 2004). Training load for each session was calculated multiplying the RPE session by the session duration obtaining the session RPE expressed in arbitrary units (AU). Each sessions training load was added together to provide a total weekly training load data, total training load included all sessions completed by the player (Tiernan, 2019).

Muscle Soreness

At the start of every monitoring test battery, players were asked to provide a measure of muscle soreness in the upper body, quadriceps, hamstring, gluteus and calf muscle on a scale from 1-10 where 10 is no pain at all and 1 is unbearable amount of pain, the researcher decided to adopt this type of scale due to mostly of the players used this method for the last three years and were trained to give a score based on this type of evaluation. The study included measures of muscles soreness from different muscle groups (upper body, quadriceps, hamstring, gluteus and calf) as part of the overall wellness monitoring procedure (Montgomery, 2013). However, players were not asked to specific any difference in soreness between left and right sides (Tavares, 2018)

Countermovement jump height

In order to measure the athletes' explosive power and monitor neuromuscular training responses, the players performed in a maximal counter movement jump test. To perform the test, players stood with feet hip width apart, facing forward, with hands on hips and with footwear. During the jumps no arm swing was permitted, as previously reported (Tavares, 2018). During the downward movement players squatted down until the knees were bent to 90 degrees of flexion, then without pausing, they jumped vertically as high as possible from two feet, landing back on the jump mat (Just Jump model by Probiotics Inc., UK) with both feet at the same time. Time taken (seconds) in an airborne state was measured and height (cm) of the jump was calculated. Participants needed to complete three jumps with correct technique during each monitoring session, with the highest jump height recorded (McLellan 2011).

Modified isometric hamstring strength

For hamstring isometric strength, participants were positioned supine with arms rested across the chest, with the heel of the foot on an inflated blood pressure cuff (DS44 Sphygmomanometer, Welch Allyn, NY, US) on an elevated platform with the leg flexed at 90° flexion and the opposite leg resting on the floor and extended. The player then pressed their heel into the cuff by isometric contractile forces of the knee flexors as previously reported (Mondin, 2018). This measurement tool was previously validated in an athletic and rugby population and also shown to be a reliable tool to indicate isometric hamstring strength (Mondin, 2018). Participants attempted this measurement method once each time on both left and right legs. The sphygmomanometer cuff was fixed on a box jump using tape, this was done to standardize the cuff position and avoid cuff movements during the test execution.

Weight bearing lunge test

The weight bearing lunge test was measured using an iPhone app. This technique has been validated by Balsalobre-Fernández, 2019 where the iPhone was placed on the upper shin of the athlete and measurements was taken by the same researcher and iPhone each time to increase validity of the test. The athlete adopted the weight bearing position in a barefoot state and flexed the ankle into maximum dorsiflexion, the angle was measured and added onto the corresponding spreadsheet on the iPad. Measurements were taken on both left and right ankles.

Adductor squeeze test

Method has been previously used by (Delahunt, 2011) where the players lied in a supine position on the floor with an inflated blood pressure cuff (DS44 Sphygmomanometer, Welch Allyn, NY, US) in between their flexed knees. Hip flexion was at 45° and knee flexion was at 90°. They then adducted both knees, applying 50% of maximum muscle contractile force to the cuff, the players then increased this contractile force to 75% and finally, 100% of muscle contraction. The maximum pressure (mmHg) value held for 3 seconds is then measured.

Statistical Analyses

To examine the correlation between markers (squeeze test, dorsiflexion angle test left and right, the difference between left and right dorsiflexion ankle, hamstring isometric test left and right, the hamstring strength isometric difference, the countermovement jumps the muscle soreness felt by players on: upper body, calf, quadriceps, hamstrings, glutes) and internal training load, a repeated measures correlation was performed.

Between week correlations were made between cumulative weekly internal training load and the marker measures on the subsequent Monday morning. Within week correlations were made between training load on a Monday and marker measures on a Tuesday and weekly cumulative training load and marker measures on a Thursday at the end of the training week. Statistical analysis was performed using R Studio software (RStudio (2020): Integrated Development Environment for R. RStudio, PBC, Boston, MA). 45 weeks of repeated measures correlation was conducted using the R package labelled “rmcorr” (Bakdash, 2017)

) in order to establish the linear association between correlations of training load and training markers for each player. The strength of the interpretation for correlation was 0–0.3 5 weak correlation, 0.3–0.7 5 moderate correlation, and 0.7–1.0 5 strong correlation, significance was set at $p < 0.05$ (Tiernan, 2019) with 95% of confidence interval (Hopkins, 2009)

Results

Training load during pre and in-season

All training weeks from the 8 weeks preseason and 37 weeks competitive season were pooled together for analysis.

During the preseason Tuesday and Thursday sessions where generally the session with more intensity and volume while on Friday mostly of the player where training on their own in doing an upper body gym session planned by the head strength and conditioning coach (Figure 3.1).

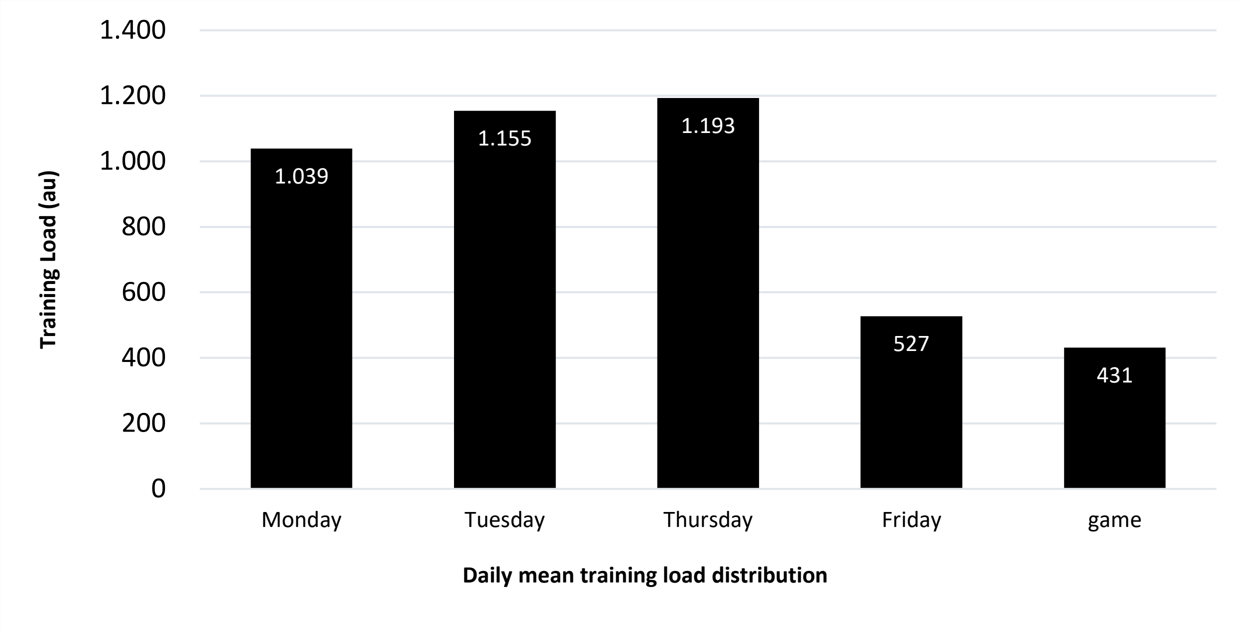


Figure 3.1 Mean distribution of preseason daily training load

The first part of the preseason presented a higher load a part for the fourth week that has been establish as active recovery week (Fig., 3.2).

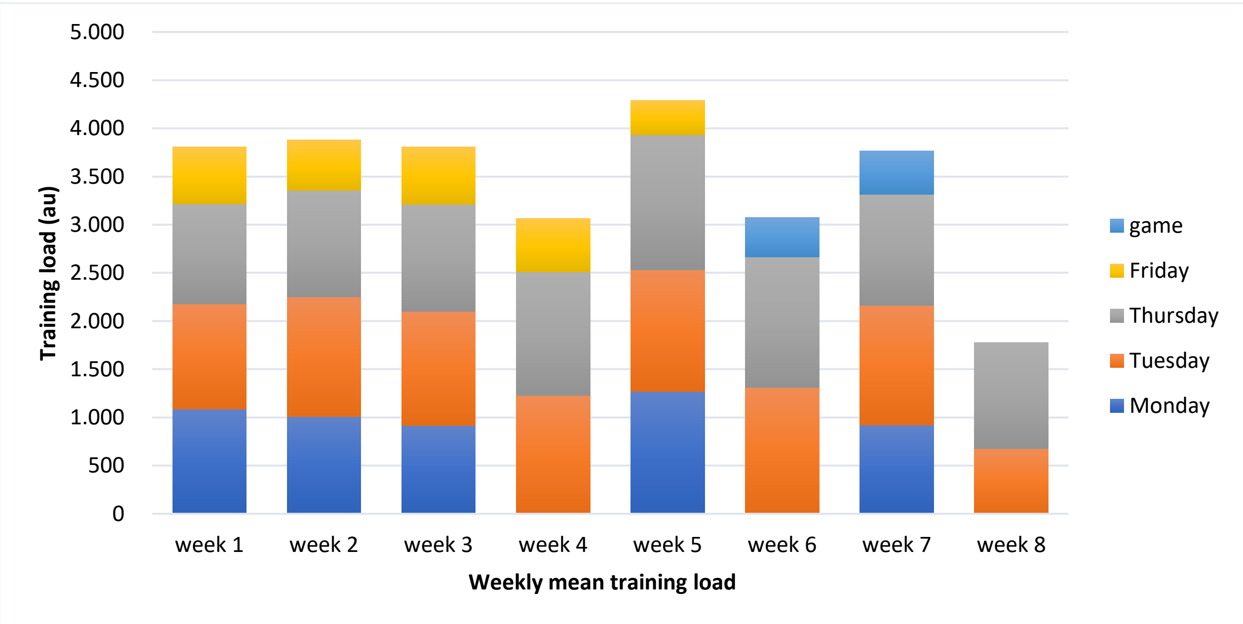


Figure 3.2 Distribution of preseason training load

The in-season period was composed by 37 weeks, with 32 games between cup and Welsh Premiership which 6 have been played on Friday while the others on Saturday. Of the 37 weeks 2 weeks were of fully recovery without any player presence on the training center, 28 training sessions have been done on Monday, 34 on Tuesday sessions and 31 on Thursday.

As it can be seen on figure 3.3, Tuesday and Thursday sessions where generally the session with more intensity and volume but obviously the match was the session with more intensity.

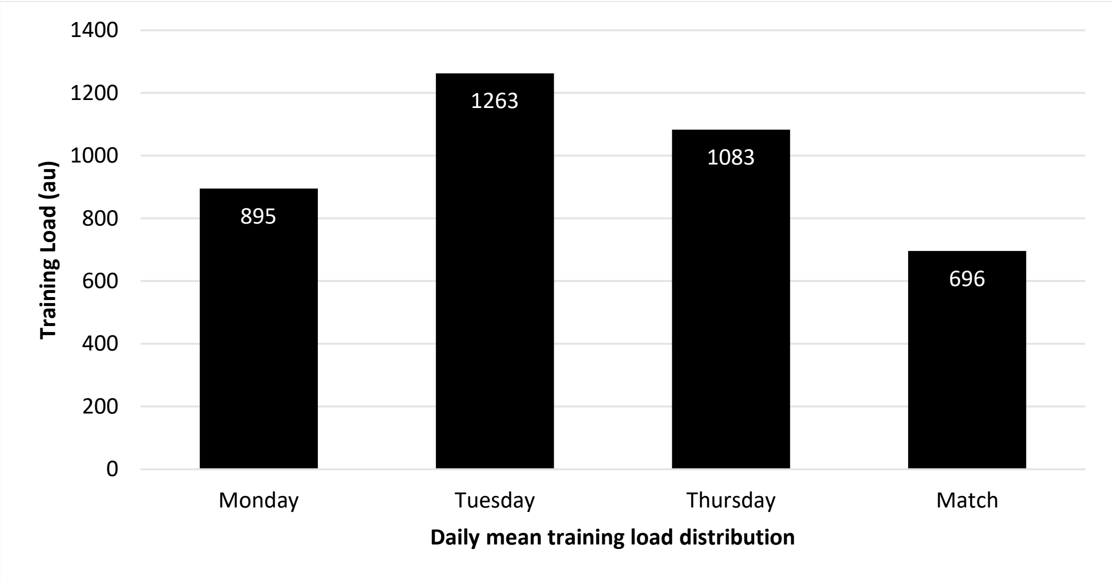


Figure 3.3 Mean distribution of In-season daily training load

The in-season load was organised with training blocks based on match difficulty and with active recovery weeks (Fig., 3.4).

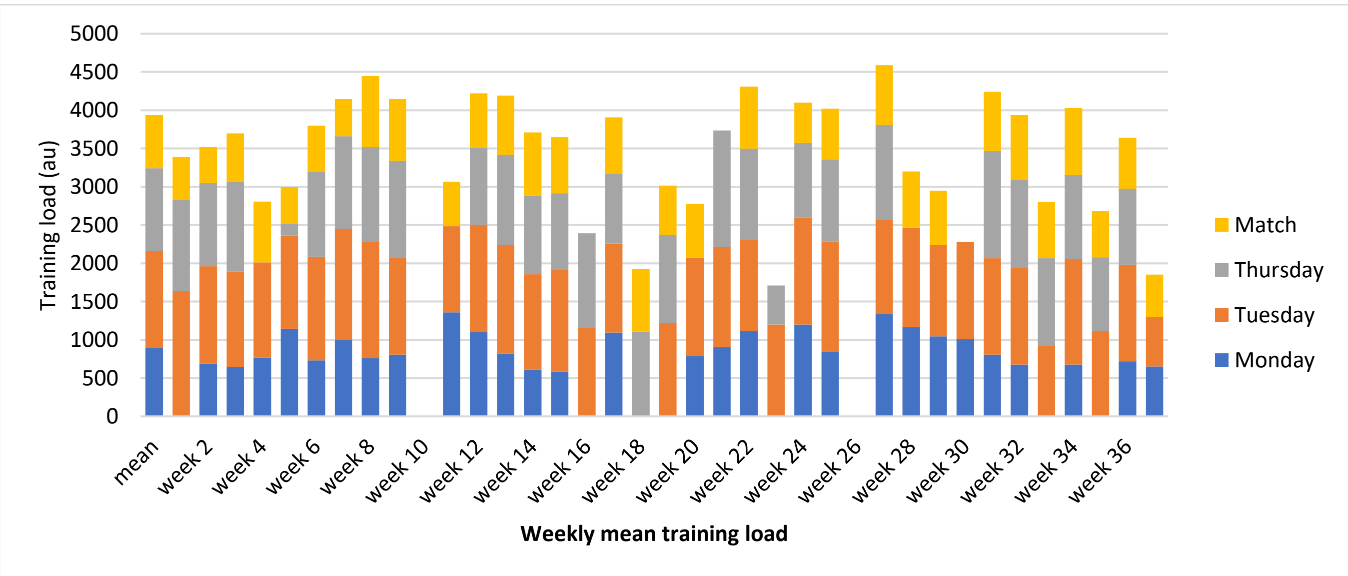


Figure 3.4 Distribution of In-season training load

<u>Between week associations of athlete monitoring markers and training load</u>

When Monday test results were correlated with the training load from the previous week, a weak negative relationship has been found between hamstring isometric strength score on both right (r= -0.115;95% CI -0.22 -0.01; *p*=0.039) and left legs (r= -0.116, 95% CI -0.22-0.01; *p*= 0.036) (Fig., 3.5) and training load;

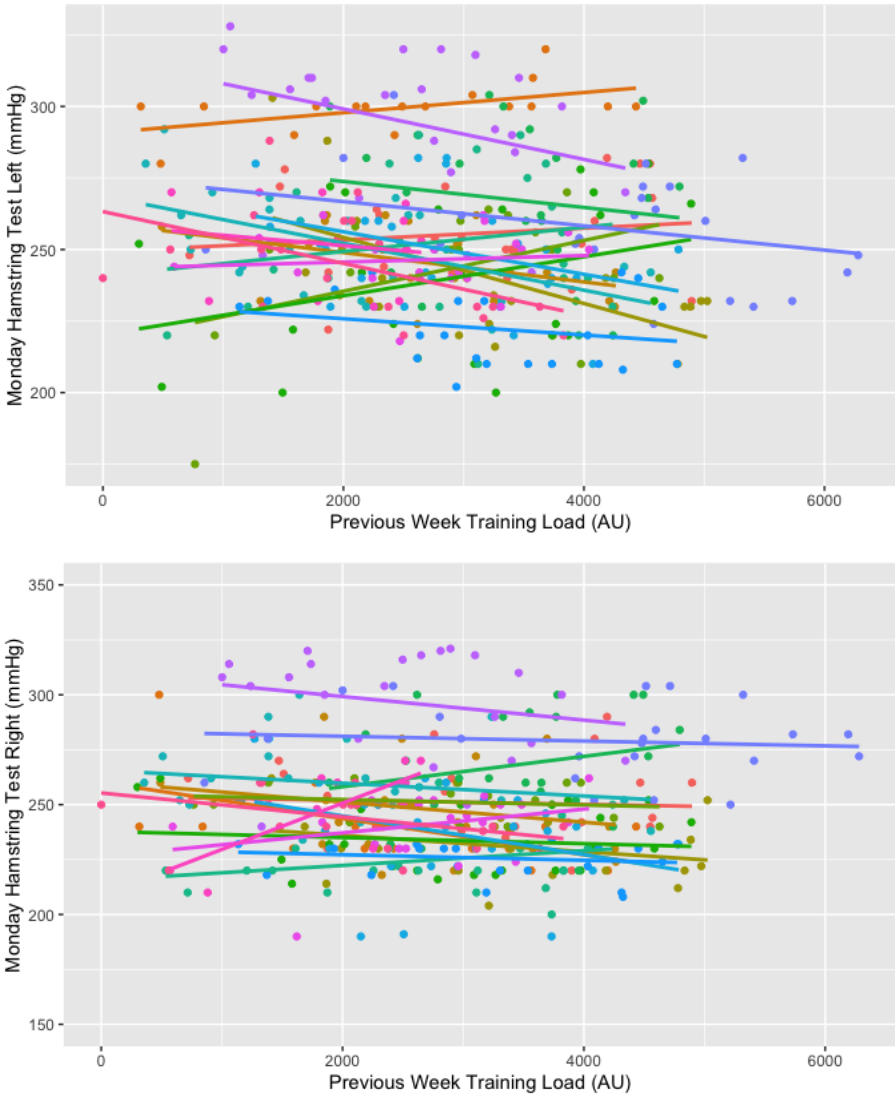
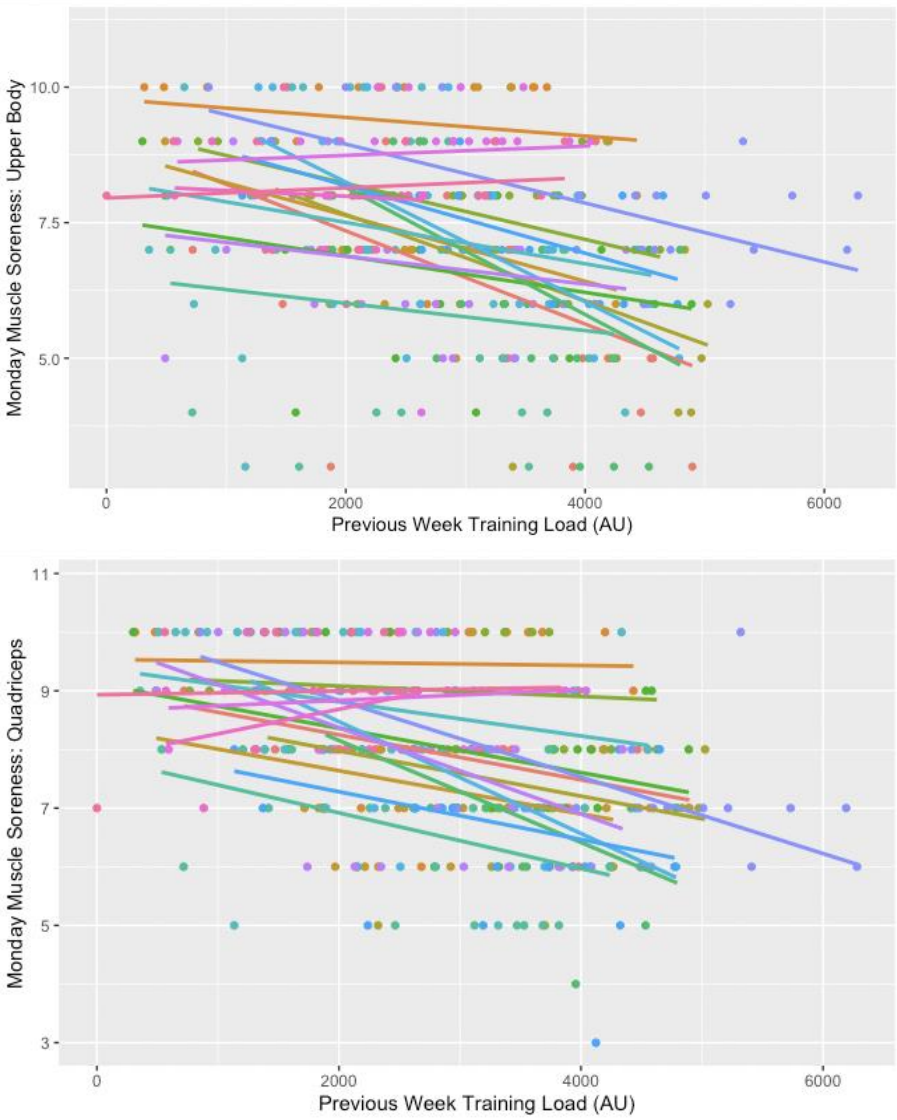


Figure 3.5 Relationship between previous week training load and Monday left and right hamstring strength (r = -0.115 and -0.116 for left and right legs respectively).

none of the other objective test were related with the cumulative training load from the previous week Adductor Squeeze test (r=0.023;95%CI-0.09 0,14; *p*=0,699) (Fig 7),CMJ (r=0.032; 95% CI-0.09 0.15; *p*=0,597) (Fig. 8), Left WBLT (r=0.099; 95%CI-0.01 0.21; *p*=0.077); Right WBLT (r=0.011;95%CI-0,10 0.12; *p*=0.845), furthermore even the difference between left and right

WBLT (r=0.073; 95% CI-0,04 0.18; p=0.190) and the difference between left and right isometric hamstring test (r=0.005; 95%CI-0.10 0.11; p=0.925) didn’t show any significant correlation with training load.

However, there was a moderate negative correlation between soreness of Upper Body (r= -0.344; 95%CI-0.44 -0.24; p=<0.001), Quadriceps (r= -0.344; 95%-0.44 -0.24; p=<0.001), Hamstrings (r= -0.328; 95%CI-0.42 -0.23; p=<0.001), Glutes (r= -0.332; 95%CI-0.43 0.2; p=<0.001) and a weak negative correlation for calf muscle soreness (r= -0.273; 95%CI -0.37-0.17; p=<0.001) with the training load from the previous week (Fig.,3.6).



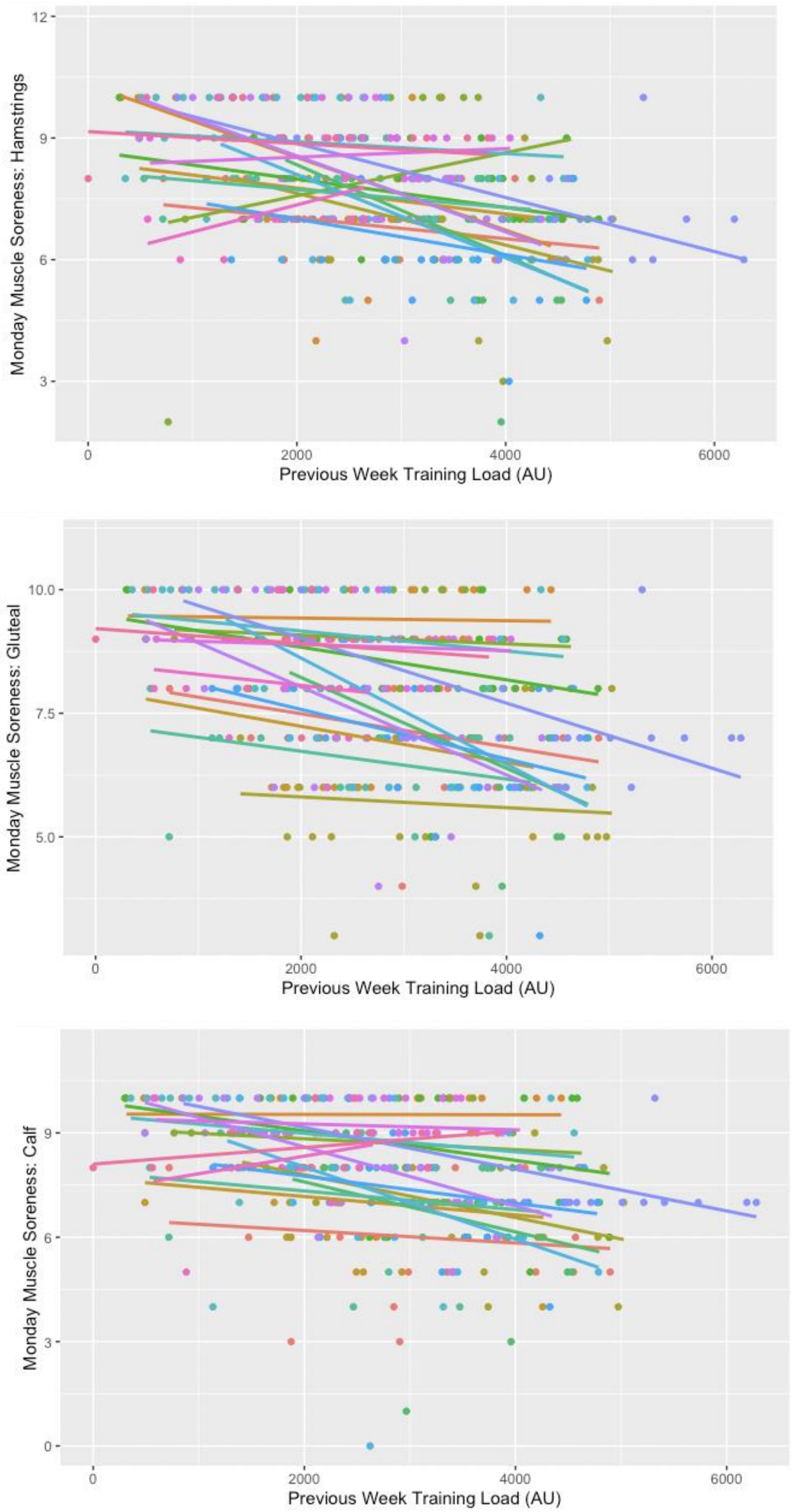
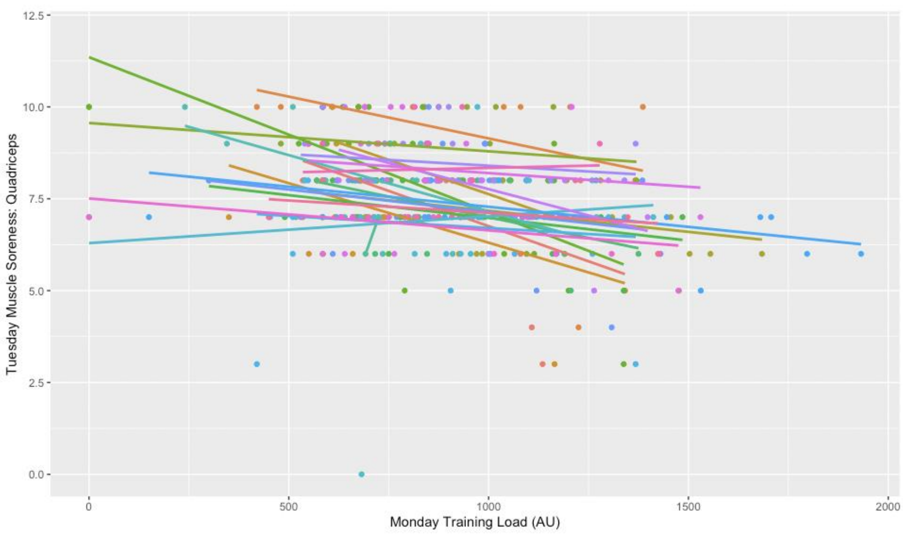


Figure 3.6 Relationship between previous week training load and Monday upper body, quadriceps, hamstring, glueteal and calf muscle soreness score (r = -0.344, -0.344, -0.328, -0.332, -0.273 for upper body, quadriceps, hamstring, glueteal and calf muscle soreness score respectively).

Within week associations of athlete monitoring markers and training load

When we correlated the Tuesday test results with the training load from the previous day, no relationship was found between the objective test scores and the training load : Adductor Squeeze test(r= 0.065; 95% CI-0.18 0.05; *p*=0.25), Left WBLT(r= -0.055;95% CI-0.16 0.05; *p*=0.31),Right WBLT (r= -0.035; 95% CI-0.14 0.07; *p*=0.51), left Isometric hamstring test (r= -0.016; 95% CI-0.12 0.09; *p*=0.76), right Isometric hamstring test(r= -0.022; 95% CI-0.13 0.08; *p*=0.67) (Fig. 11) , furthermore none of the difference between left and right WBLT (r= -0.004; 95% CI-0.11 0.10; *p*=0.93) and hamstring isometric test (r= -0.073; 95% CI-0.18 0.03; *p*=0.17) showed any significant correlation.

However, all ratings of muscle soreness score were associated with the training load from the previous day respectively Quadriceps (r= -0.339; 95% CI-0.43 -0.24; *p*=<0.001), Hamstrings (r= -0.309; 95% CI-0.40 -0.21; *p*=<0.001), Glutes (r= -0.40; 95%CI-0.21 -0.310; *p*=<0.001), showing a moderate negative correlation. Apart for Calf (r= -0,207; 95% CI-0,30 -0,10; *p*=<0.001) that showed a weak negative relationship and Upper Body (r= 0.235; 95% CI 0.13 0.33; *p*=<0.001) (Fig.,3.7) that showed a weak positive correlation; therefore, the Tuesday upper body soreness didn't decrease when the total load increase and vice versa.



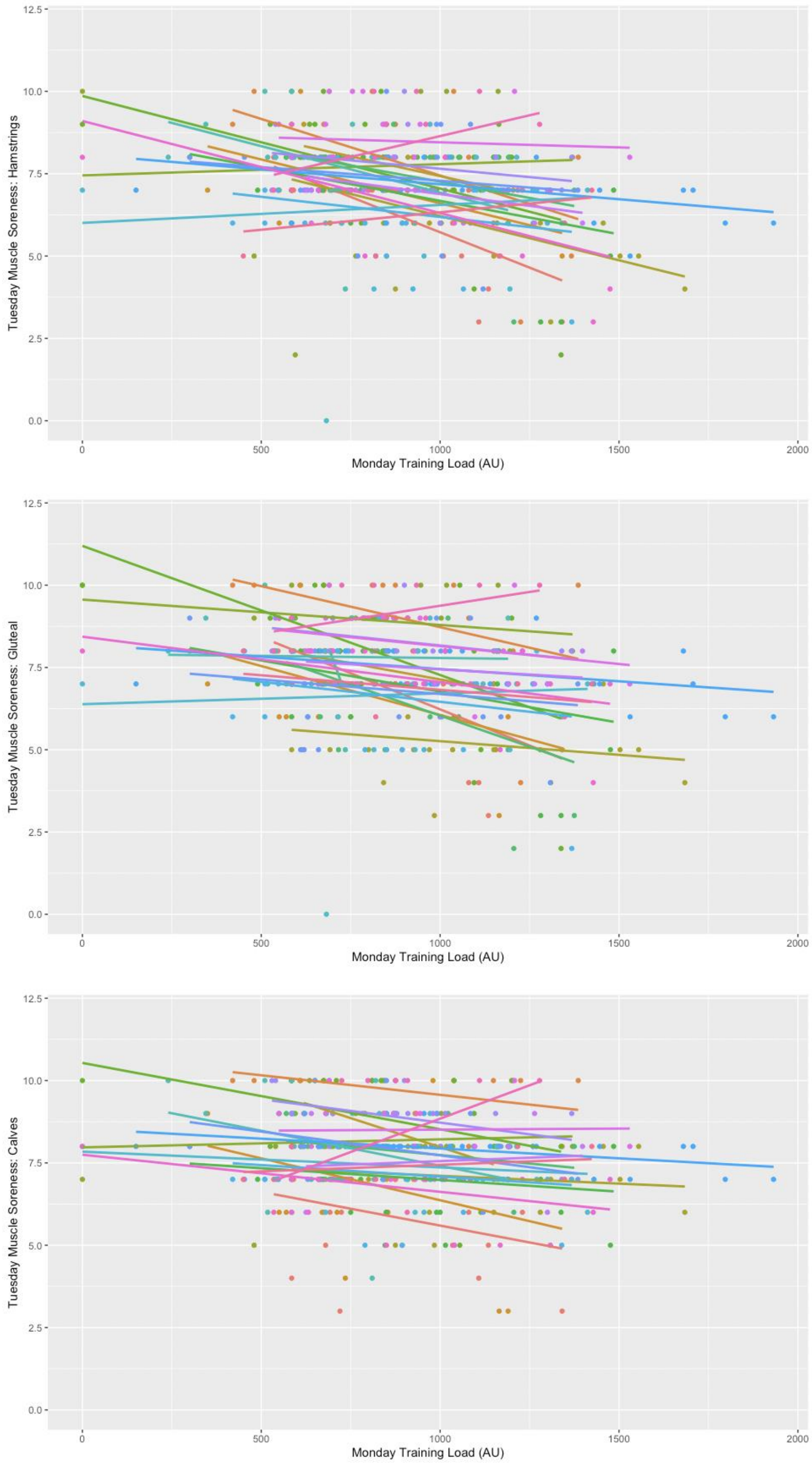
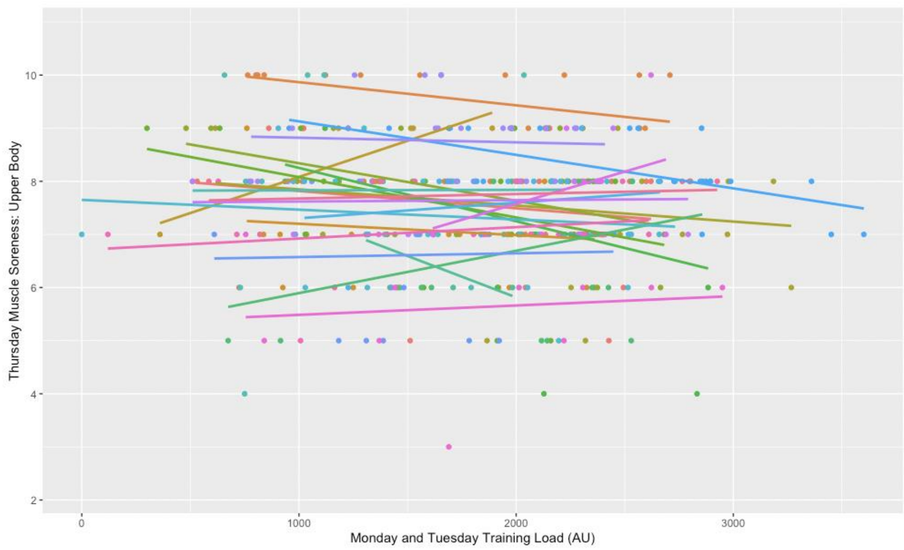
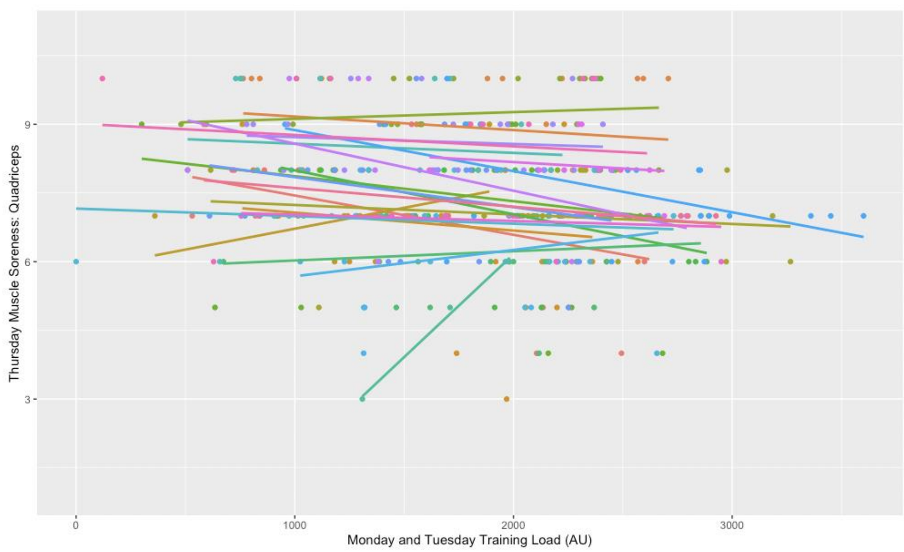


Figure 3.7 Relationship between Monday training load and Tuesday quadriceps, hamstring, glueteal and calf muscle soreness score (r = -0.339, -0.309, -0.40, -0,207 quadriceps, hamstring, glueteal and calf muscle soreness score respectively).

When we correlated the morning Thursday tests results with the cumulative training load from the current week, again there was no relationship between the objective test scores and training load: Adductor Squeeze test (r=0.001; 95% CI-0.12 0.12; *p*=0.991), left WBLT (r= 0.060; 95% CI-0.05 0.17; *p*=0.288), right WBLT (r= 0.056; 95% CI-0.05 0.16; *p*=0.307), left Isometric hamstring test (r= -0.007; 95% CI-0.11 0.10; *p*=0.901), right Isometric hamstring test (r=0.017; 95% CI-0.09 0.12; *p*=0.750) and the difference between left and right WBLT (r= 0.059; 95%CI -0.05 0.17; *p*=0.288) and left to right hamstring test (r= -0.053; 95%CI-0.16 0.06; *p*=0.336). However, all ratings of muscle soreness showed weak negative correlations with the training load from the current week Upper Body (r= -0.117; 95% CI-0.22 -0.01; *p*=<0.001), Quadriceps (r= -0.177; 95%CI -0.28 -0.07; *p*=<0.001), Hamstrings (r= -0.220; 95% CI -0.32 -0.12; *p*=<0.001), Glutes (r= -0.247;95% CI 0.34 -0.14; *p*=<0.001), Calf (r= -0.137;95% CI=-0.24 -0.03; *p*=<0.001) (Fig.,3.8).





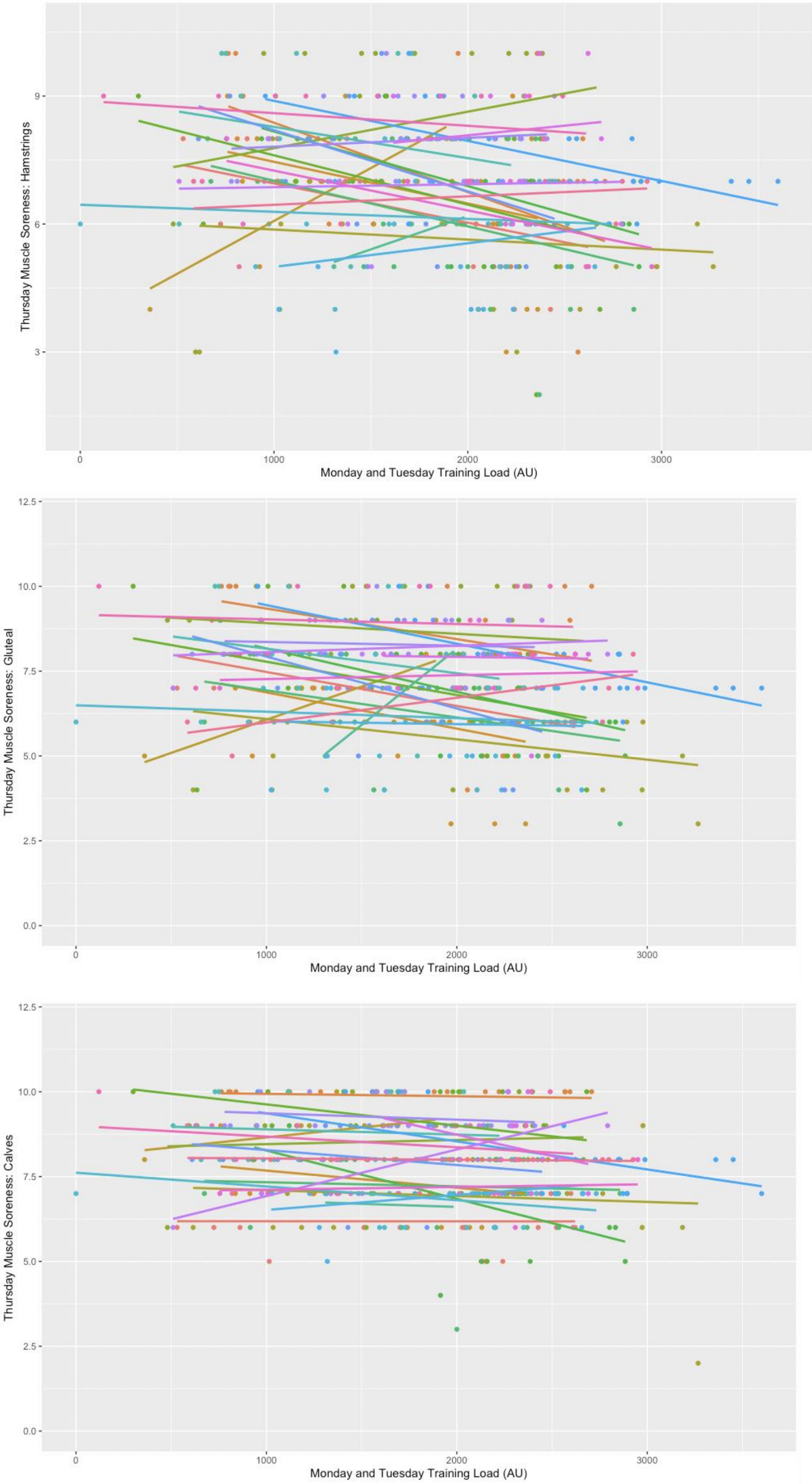


Figure 3.8 Relationship between Monday and Tuesday training load and Thursday upper body quadriceps, hamstring, glueteal and calf muscle soreness score (r = -0.117, -0.177, -0.220, -0.247, -0.137 upper body, quadriceps, hamstring, glueteal and calf muscle soreness score respectively).

Discussion

This is the first study of its kind to track CMJ, squeeze test, WBLT, hamstring isometric strength and muscle soreness (upper body, calves, quadriceps, hamstring, glutes) over an entire season which included both the full preseason and in-season periods investigating its association to weekly training load in professional Rugby Union players. The results found that as weekly training load increased, Monday hamstring isometric strength test for both left and right legs and muscle soreness score of every muscle district considered significantly decreased (on the scale used in this study: 1-10 where 10 is no pain at all and 1 is unbearable amount of pain), partially confirming the hypothesis of a correlation between load accumulation and subjective and objective training markers.

Monday monitoring scores were compared with the previous weeks training, while Tuesday and Thursday monitoring scores were compared with the same weeks training. Additionally, it was found as players' perceived muscles soreness increase, that means that muscle soreness score decreased, and Monday and Tuesday load increased. The results indicated that only hamstring isometric strength test and muscle soreness were correlated to the previous week training load and only the muscle soreness where sensible to within week training load variation, indeed, looking at Figure 3.5 it is possible to note the negative relationship between load and hamstring isometric strength test; indeed, the lines of left and right hamstring tests are showing a downward trend while the load is increasing. Looking at muscle soreness it is possible to note a clear downward trend of the line of every plot presented (Monday, Fig.3.6; Tuesday, Fig.,3.7; Thursday Fig.,3.8) as answer to the training load increase , this clearly highlight how muscle soreness demonstrated to be sensible to accumulated change of load of the previous week and acute load changes of the same week, the only muscle soreness score that bucks the trend has been the upper body soreness recorded on Tuesday morning, it showed a positive correlation (r= 0.235) on its relationship with Monday training load.

To the authors knowledge, only few previous studies have explored the relationship between subjective and objective training markers and training load. One of these studies tracked adductor squeeze strength over a preseason training period and investigate its association to weekly training load in elite Rugby Union players (Tiernan 2019), it found a weak negative correlation between Monday adductor squeeze strength scores and the previous weeks training load ($r = 0.235$; p , 0.05), and Friday adductor squeeze strength scores and the same weeks training load ($r = 0.211$; R2 5 4.5%; p , 0.05),which contradicts the findings in the current study that didn't find any correlation with adductor squeeze test and training load , a possible explanation can be that Tiernan, 2019 study considered only the preseason period that generally presents a more linear training load increasing and less acute load variation, furthermore his statistical approach has been different , indeed he used a Spearman's correlation that as the Pearson correlation can lead to a lower level of statistical precision compared to the repeated measures correlation conducted using the R package utilized in the current study with the objective to establish the linear association between correlations of training load and training markers for each player.

Another study that investigated 42 Australian football (AF) players during the entire competitive season support the idea that resting heart rate, CMJ test, perceptual wellness test all possess acceptable sensitivity and therefore can be used by coaches and scientists of professional AF teams to identify meaningful changes in athletes training responses (Ryan, 2020), our findings confirm the subjective self-perceived recovery method, in our case only the muscle soreness score, as sensitivity method to measure the fatigue and recovery athlete status but doesn't confirm Ryan (2020) results about the sensitivity of CMJ, indeed we didn't find any significant correlation between CMJ and training load. However, the two papers are difficult to compare, especially considering the two different analysis methods, indeed Ryan (2020) use a coefficient of variation percentage (CV%) and intraclass coefficients and calculated the sensitivity dividing weekly CV% by test CV% to produce a signal to noise ratio while we looked at a correlation between training load and monitoring scores.

Even if for just 1 week period another paper investigated the relationship between training load and subjective and objective training markers on professional rugby players (Tavares, 2018), founding a clear effect of training load on soreness and CMJ , with greater overreaching following two training days in a row when compared to a single training day, their finding match with the current paper finds supporting the idea of muscle soreness as sensible tool, able to answer to load change however we didn’t find any correlation between load and CMJ test. Tavares, 2018 had a different approach to the problem indeed it looked at how during the week the countermovement jump changed compared to its baseline after a rugby match, we considered an entire season of rugby and the training periodization could potentially interfere with the CMJ baseline, so this type of approach couldn’t fit with our paper possible design.

This is the first study to investigate and find a relationship between hamstring isometric strength test scores and total load. These findings mean that if a player show a decrement in this test, he could be sore or maladapted and this could be a first alarm for the coach staff about an additional recovery time needs from the player or possibly an accumulation of overload. Previous research has principally investigated subjective markers of recovery and their relationship with training load (Tiernan 2019; Tavares, 2018). The previous research found that subjective markers of recovery or muscle soreness could be used to help coaches make informed decisions on a player’s readiness to train, our findings confirm this theory but additionally underline the fact that compared to objective markers of training, muscle soreness could be the only markers sensible to within week load changes. Additionally, previous work has shown that CMJ (Ryan, 2020; Tavares, 2018, Taylor, 2012; McClean, 2010; Cormack, 2008) and squeeze test (Tiernan, 2019, Delahunt, 2017; Roe, 2016; Buchheit, 2017) could be sensible to load changes.

Perspectives

Limitations of this study could be that the data were collected from only one rugby team, despite the sample size was even bigger if compared to similar papers (Tiernan, 2019), include more rugby teams could give more power to the results, in addition, no external load data, such as global positioning system, were collected which may provide further external load metrics (such as distance covered each session) even if RPE is largely validated as measure of training load (Manzi, 2010; Impellizzeri, 2004; Foster, 2001).

The strength and the weakness of this study is that it has been done in a practical setting in a normal training activity of the rugby team, the two main problem that have probably changed the study results could be the fact the team training session were executed only three days a week and it was not possible to record the data of the player activity during their free time, for the same reason the activity during the weekend was not impossible to record so the different activity during their free time could interfere on the optimum recovery between the last activity and the first monitoring test. Another fact that could interfere on recording signs of overload is the fact that if during the morning test score a player resulted particularly negative, the team physiotherapist was free to modify the player training load or actively help him to recover.

A monitoring test battery is a useful tool that allow coaches to understand players readiness, recognise signs of maladaptation and possibly prevent fatigue accumulation that could enhance injuries risks or underperformance, in a team sport it becomes even more important to allow to the coach to personalize the athlete training based on their training responses answer to the training load optimizing the ratio between training load and recovery.

The test battery has to be composed by different type of test able to describe the multitude aspect of possible overreaching, furthermore it is essential that a monitoring test battery and the chosen monitoring tools would be sensible to training load variation, this would allow coaches to managing the training load checking the relationship between training input, athlete’s adaptation and recovery. In the current study we chose test that have potentially showed to be sensible to change of training load and that could give a useful feedback to a professional rugby team about the player's readiness, for these purposes the choice of the morning test has followed rugby specific rationale and general rugby injury surveillances and prevention.

This study demonstrated an association between few of possible training markers and training load dose, future research are necessary to verify if these could be clinically relevant, indeed it would be helpful, for coaches and medical staff if future studies would investigate if these type of test would be possible correlated with injury helping on injury prevention and if a recovery intervention based on a monitoring system, able to recognise signs of maladaptations, could reduce the number of injuries and overtraining syndromes in sport and specifically in rugby.

Practical Applications

These results may help strength and conditioning coaches to choose what tests to use in their monitoring tests battery, knowing what tests could be sensible to change in training load dose and possibly be able to provide information about first sign of maladaptation avoiding non-functional overreaching. However, the results from this study must be interpreted with caution because for example the hamstring isometric test showed only a weak correlation. Considering this degree of caution, the coach could use the soreness questionnaire as described in thesis to understand if the load change could affect the players recovery during the week potentially managing the training load within the week, furthermore the soreness questionnaire in combination with hamstring strength test could be used before starting the first training day of the week to recognize possible first sing of maladaptation caused by a possible excessive load during the previous week and consequently adjust the load dose during the coming week.

Conclusion

This paper investigated on few of the most common used subjective and objective monitoring tests that in previous paper showed validity as training markers, our data showed that hamstring isometric strength test and soreness are sensible tools to detect a training response as answer to change in training load, while CMJ, adductor squeeze test and WBLT didn't show the same efficacy. To detect the training responses caused from within load changes the only tools that demonstrated efficacy have been muscle soreness score.

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APPENDICES

Prifysgol Bangor University
YSGOL GWYDDORAU CHWARAEON, IECHYD AC YMARFER
SCHOOL OF SPORT, HEALTH AND EXERCISE SCIENCES

Please complete all parts of this form.
Please attach consent and information/debriefing sheets to all applications

Type of project requiring approval (*tick one box only*)

☐ Staff project ☐ PhD project

☑ Masters by Research project ☐ Undergraduate project

☐ Class demonstration

1	Title of project	Athlete monitoring to help predict injury, illness and underperformance in rugby union players.
2	Name and e-mail address(es) of all researcher(s)	Mr Davide Mondin – d23mondin@gmail.com Mr Reece Smith – peu6cf@bangor.ac.uk
3	Name and e-mail address of supervisor (for student research)	Dr Julian Owen – j.owen@bangor.ac.uk Dr James Hardy – j.t.hardy@bangor.ac.uk Dr Eleri Jones – eleri.s.jones@bangor.ac.uk Mr Gareth Whittaker – GWhittaker@wru.wales
4	Proposed starting date	28th June 2018
5	Proposed duration	2 months
6	What is your research question?	Can individual psychological and physiological marker or combinations of these markers be used to predict impending under-performance, illness, and injury in rugby union players.

7 Briefly explain the aims and relevance of your proposed study. Also outline the methodology (1/2 page maximum; express yourself in lay terms i.e. so that it is understandable to a non-specialist in the area)

Athletes are uniquely placed as they are exposed to chronic and frequently intense physical and mental stressors. These stressors can potentially shift physical and psychological well-being along a “problematic” continuum that progresses beyond a normal response to training to a state called over-reaching or burnout, and ultimately underperformance, illness and injury. To combat these issues, monitoring athletes during the training process to attempt to predict an increased risk of injury, illness and underperformance has been a rapidly emerging topic of research in sport and exercise sciences over recent years. Traditionally, research based on athletic populations have examined numerous contributing factors or “markers” of poor performance and ill health (e.g. physiological, hormonal, immune, performance, psychological and subjective measures). However, there is yet to be a single, definitive marker described in the literature. A stronger research paradigm places an emphasis on monitoring multiple markers in a within-subject, individualised and longitudinal manner, enabling a better understanding of how fluctuations in markers predict the progression towards negative health outcomes and associated poor performance. In addition, to date over-reaching and burnout-oriented research has been firmly grounded in either a physiological or psychological paradigm; there has been no systematic attempt to integrate both perspectives. Such research has likely been hampered by an inability to appropriately analyse data sets involving relatively few but closely monitored participants. However, innovative techniques such as pattern recognition analyses, may provide an alternative statistical approach to this problem.

Aim: to develop a systems-approach to athlete monitoring within the senior and academy rugby union squads at Rygbi Gogledd Cymru (RGC). The specific goals of the project is to complete longitudinal monitoring of RGC rugby players using multiple holistic markers, to identify markers or combinations of markers which can predict and underpin impending under-performance, illness, and injury.

Methodology: The initial part of this 12-month project will involve athlete monitoring over the 8-week pre-season period. This will include initial psychological profiling, followed by a systematic monitoring of markers of performance, well-being and mood **(please see full methodological proposal for details)**.

8 Briefly describe the subjects you are planning to use in your study (include age, gender, and special status, e.g. children, learning disabled, vulnerable people).

Participants will be professional and semi-professional senior (over 18) and academy (under 18, range 15-18) rugby union players from the RGC senior team and WRU North Wales Regional academy.

9 Describe how you are going to recruit your participants.

All participants will be recruited from the senior and academy squads of RGC. Initially a series of presentations, outlining the purpose and methodology of the research, will be delivered to players (and parents in the case of academy players) before the beginning of the pre-season period at the end of June 2018. At the end of these sessions, players (and parents) will receive participant information sheets which they will be allowed to take away and digest before either agreeing to participate or not.

10 Where will the study take place, e.g. university, school, hospital, athletic club?

The study will take place at the training centre for RGC; Eirias Park, Abergele Road, Colwyn Bay, LL29 7SP.

11 How much time will each subject be required to give up for your research project (including travelling time)?

This is outlined in more detail in the full methodological proposal and in the participant information sheets. In summary, participants will be required to spend an additional hour a week over the 8-week pre-season period carrying out monitoring tasks.

12 Do you intend to pay participants for their participation?

☐ YES ☑ NO

If yes, what form will the payment take?

13 What are the risks to participants (physical and/or psychological)?

Please explain fully what the risks are, how you plan to mitigate these, and **justify their necessity**.

Apart from the obvious risk of routine rugby training, match-play, physical testing and player monitoring, we envisage no additional risk to the players based on the additional monitoring procedures as part of the research project. These will include measuring morning heart rate variability, monitoring psychological traits and states and assessing mood via mobile applications. In addition, we will be collecting saliva at two time points during the pre-season period. This will be collected in sterile vials and there is no added risk to the participants.

14 The following research activities are considered to involve more than minimal risk and, consequently, require ethical review by the SSHES Ethics Committee.

Does your research involve any of the activities?

		YES	NO
i	NHS patients either in hospital or general practice?		✓
ii	Vulnerable groups? e.g., children and young people (i.e. under 18 years), those with a learning disability or cognitive impairment, or individuals in a dependent or unequal relationship.	✓	
iii	Sensitive topics? e.g., participants' sexual behaviour, their ille.g.al or political behaviour, their experience of violence, their abuse or exploitation, their mental health, or their gender or ethnic status.		✓
iv	Groups where permission of a gatekeeper is normally required for initial access to members?		✓
v	Deception or activities which are conducted without participants' full and informed consent at the time the study is carried out? If yes, i) please outline the alternative methodological approaches to your problem that you have discarded. It is simply not enough to say that you cannot obtain the data without the use of deception. You must indicate that you have considered other methodological approaches and that these were not appropriate. ii) in your opinion could the deception cause distress in subjects?		✓
vi	Access to records of personal or confidential information, including genetic and other biological information, concerning identifiable individuals?		✓
vii	Activities which might induce longer term psychological stress, anxiety or humiliation?		✓
viii	Intrusive interventions? e.g., the administration of drugs or other substances, vigorous physical exercise in people deemed 'at risk' (see PAR-Q below), or exposure to extreme physical or psychological conditions which could be injurious.		✓

IF YOU HAVE ANSWERED **YES** TO ANY OF THESE ACTIVITIES (FOR v, THIS ALSO REQUIRES 'YES' FOR vii) THEN YOUR PROJECT MUST BE REFERRED TO THE ETHICS COMMITTEE

(See also NOTES – Insurance cover against Litigation)

15 How are you going to handle the requirement of confidentiality?

For the purpose of the research project - All personal information collected during the study will be kept confidential (within the research team named at the beginning of this form) and all player data will be anonymised by replacing names with participant codes, and kept for a period of 5-years. In addition, information collected will include player age, injury history and training history. Only the designated research students and supervisory team will have access to participant's personal data during the study. All data collected will be stored on password protected WRU and Bangor University computers. Saliva samples collected during the research project will be anonymised using codes, so that players samples will not be identifiable. These will be stored in -80^{o}C freezers in the laboratories of the School of Sport, Health and Exercise Sciences. These samples will be stored for a period of five years and used to measure individual immune, inflammatory and hormone response to training.

Some of the collected data during the project (see below for details) will form an additional part of the current RGC player monitoring process. Therefore, this data will not be anonymised as it will be used to inform the training progression of individual players on a day-to-day basis. This data will only be available to the RGC management (Head coach – Mr Marc Jones and Assistant Coach – Mr Phillip John) and RGC sport science and medical staff (Director of Performance – Mr Josh Leach, Head of Strength & Conditioning – Mr Gareth Whittaker, Head of Physiotherapy – Mr Oran Elphinstone Davies). These data will include:

- Daily heart rate variability scores
- Heart rate during on-field training sessions
- Daily ratings of mood and well-being
- Daily counter-movement jump and reactive strength index tests.

16 During your data collection will supervision or assistance be required (e.g. for experiments in the physiology laboratory)?

YES ☑ NO ☐

If yes, how will supervision be arranged?

Initial field-based supervision of the Masters by Research and MRes students will be provided by the primary supervisor (week one) and thereafter by the Head of Strength & Conditioning for the WRU North Wales Region (Mr Gareth Whittaker).

17 How will you obtain informed consent?

i) How will you inform the subject about what is going to happen to him/her?

Presentations will be delivered to senior players, and academy players and their parents at the beginning of pre-season (end of June 2018). These presentations will outline the purpose and requirements of the research project. In addition, potential participants will receive information sheets to take away and read before deciding to give consent.

ii) How will the subject give consent?

All potential eligible participants will receive consent forms and detailed information sheets explaining the research in full, and contact details in order to receive further study information.

Participants will be informed that they may withdraw from the study at any time without giving a particular reason and that this would not affect their relationship with SSHES or staff at RGC.

iii) Does the project involve children?

☑ YES ☐ NO

If yes,

- Children under the age of 16, their own consent (where possible) and parental/guardian consent is required (this must be written consent).
- Individuals aged over 16 and under 18 years, only their own consent is legally necessary (this must be written consent), but parental/guardian consent is desirable.

iv) People belonging to vulnerable groups?

☐ YES ☑ NO

If yes,

- Parental/guardian consent is required. If this would offend the dignity of the participant, exception may be made for participants over the age of 18.

18 **Is parental/guardian consent required for your project?**

☑ YES ☐ NO

Most of the academy players will be under 18 (approximately half of the sample). We will seek parental consent for these participants if they decide to participate in the study.

19 If your project requires you to have access to children under the age of 18, police screening needs to be carried out. This requires a Disclosure and Barring Service (DBS) Form to be completed (ask the SSHES School Manager for more information).

Does police screening need to be carried out?

☑ YES ☐ NO

The primary supervisor has an enhanced DBS clearance and similar will be sought for Mr Davide Mondin and Mr Reece Smith via the WRU safeguarding procedures.

…………………………………. …………………………….. …………………..

Signature of applicant Print Name Date

ETHICS APPROVAL ACTION

Take into account the responses to this form with particular reference to the activities listed in Q14

☐ **This project already has approval under SSHES Ethics No. ____________**

(Contact Mark Chitty if you are unsure of the Ethics Register number; submit completed form to the General Office)

……………………………………. ……………………..………. ………….......

Signature – supervising staff member Print Name Date

☐ **This project does NOT require referral to the Ethics Committee**
(Submit completed form to the General Office)

………………………………………. ……………………….……. ....

Signature – supervising staff member Print Name Date

………………………………………. ……………………..……..... ....

Signature of second staff member Print Name Date
(e.g. cross moderator for student projects)

………………………………………. ……………………..……..... ....

Signature of third staff member Print Name Date
(e.g. member of Ethics Committee)

■ **This project requires referral to the Ethics Committee**

Submit this form, the information sheet, the customised consent form (Form 2 or 3 as appropriate) and the protocol to the SSHES Ethics Committee for consideration and approval.

If approved, Ethics Committee Chair to sign below in addition to the supervising staff member.

…………………………………………. ……………………..……….. ....
Signature – supervising staff member Print Name Date

Anthony Blanchfield 27/06/18
Signature granting approval by Print Name Date
Chair of Ethics Committee
(*Dr Anthony Blanchfield)*

This completed and signed form must be submitted to the General Office for registration on the SSHES Ethics Register before data collection may commence.

PARTICIPANT INFORMATION SHEET

(VERSION 1.0 – 18/05/2018)

PRIFYSGOL BANGOR UNIVERSITY

School of Sport, Health and Exercise Sciences
Bangor University,
George Building,
Bangor,
Gwynedd, LL57 2PZ

Title of study: Athlete monitoring to help predict injury, illness and underperformance in rugby union players.

Masters by Research Student
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Supervisory team
Dr James Hardy[1]
Dr Eleri Jones[1]
Gareth Whittaker[2]

[1] School of Sport, Health and Exercise Sciences, Bangor University.
[2] Welsh Rugby Union Group / Grwp Undeb Rygbi Cymru, Eirias Park, Abergele Road, Colwyn Bay.

Invitation to take part

You are being invited to take part in a research study, as a member of the Rygbi Gogledd Cymru (RGC) squad of players. Before you agree to take part, it is important for you to understand why the research is being done and what it will involve. Please take time to read the following information carefully. If you wish, please discuss it with friends, relatives or staff at RGC. Please ask us if there is anything that is not clear or if you would like more information. Take time to decide whether you wish to take part, or not.

What is the background of the study?

The balance between training and recovery is important to make sure athletes continue to improve. Too much training and/or too little recovery for long periods of time mean that athletes become more prone to injury, illness (such as cold and flu) and a decrease in performance, often called athlete burnout, overreaching or overtraining. Therefore, it is common practice in sport to monitor athletes during the training process. Monitoring tools include; assessing the amount of training an athlete completes, the athlete's response to this training, how the athlete feels (e.g. muscle soreness or mood), assessing performance (e.g. jumps tests or other fitness tests) and monitoring heart rate at rest and during training. Sometimes sport scientists will measure the hormonal response to training or how well the immune system is working. Despite lots of research in this area we still do not have a fool proof method for predicting when athletes are training too much or not recovering enough. We believe that monitoring both psychological and physiological responses during a heavy training period (e.g. pre-season) may provide answers to this question. Therefore, the aim of this research study is to measure some of these psychological and physiological monitoring tools during pre-season training to see if they are related. The findings of the study may help us develop ways of identifying athletes at risk of injury, illness and underperformance.

Do I have to take part?

This is entirely your decision. If you decide to take part you will be given this information sheet to keep and be asked to read and sign a consent form during the first session. Even if you decide to take part in the study **you are free to withdraw at any time point without giving a reason** and this will not affect your relationship with the School of Sport, Health, and Exercise Sciences, RGC or any of the researchers involved. **Any information collected during the study will be treated confidentially.**

What is required of me if I take part?

As a player within the RGC structure you will have undergone certain athlete monitoring tasks as part of your training routine, including recording your session RPE scores, muscle soreness ratings, assessing vertical jumps scores, taking part in physical tests and occasionally had your heart rate monitored during training. This research project will expand on the monitoring you already do as part of your involvement in the squad. The outline of these new aspects of the monitoring system are shown on the next page:

Current athlete monitoring tools	**New athlete monitoring tools**

Session RPE sent to S&C coach after each training session.	This will remain the same
Physical fitness tests	This will remain the same
Scoring and sending information to S&C coach regarding athlete well-being e.g. muscle soreness	The system will remain the same. **Addition -** we will ask you to complete some additional questions including, quality of sleep, level of recovery, how fatigued you feel, and also your mood.
Counter movement jump and drop jump testing	Again, this will remain the same. **Addition -** we will be using some newly purchased accelerometers which will also measure the speed of the jumps.
Heart rate monitoring during training sessions.	This aspect of monitoring will remain the same as last season. **Addition** – we will be giving you a Bluetooth heart rate chest strap and will ask you to measure your heart rate for 5 minutes every morning before breakfast. Alongside a free downloadable app, this will allow us to measure how your heart rate variability changes with training.
Injury prediction tests e.g. squeeze tests and ankle dorsiflexion test	This will remain the same
	Online questionnaires. Before the start of pre-season, we will be sending you links to complete some online questionnaires including ones assessing your personality e.g. level of anxiety, how you deal with emotions and resilience. We will also send you links to complete some other psychological questionnaires measuring motivation, how you feel (interoception) and a questionnaire on athlete burnout. We will ask you to fill in some of these questionnaires every two-weeks via an online link including; interoception, anxiety and burnout. A full list of these questionnaire is included at the end of this form.
	Saliva sample to measure immune and hormonal measures – every two weeks during pre-season we will ask you to provide a saliva sample into a plastic sealable container. To do this you will simply drool into the container for 5 minutes. We will store this saliva at the University for later biochemistry assessment of hormone (testosterone and cortisol) and immune function markers (alpha amylase and immunoglobulin A).

What do I have to do?

You simply continue with the training and competition requirements of RGC. There are no additional lifestyle or nutritional restrictions from taking part in this study. All additional requirements listed in the table will be organised and directed by the S&C and medical staff at RGC.

What are the possible disadvantages and risks of taking part?

There are no additional risks of taking part in this study. There is an additional time commitment with filling out questionnaires at the start of pre-season, measuring morning heart rate, and additional questionnaires during the pre-season period, these are outlined below:

Time commitment during the 8-week pre-season period

New monitoring system	Time commitment each day	Time commitment each week	Time commitment over the pre-season
Beginning of pre-season online questionnaires	N/A	N/A	30-45 minutes
Morning heart rate monitoring	5 minutes per day (5 days per week)	25 minutes	200 minutes
Addition well-being questions	5 minutes per day (5 days per week)	25 minutes	200 minutes
Additional questionnaires	N/A	20 minutes (every two-weeks)	80 minutes
Saliva samples	N/A	5 minutes (every two-weeks)	20 minutes
Total	**10 minutes**	**62 minutes**	**545 minutes over 8-weeks**

What are the possible benefits of taking part?

By participating in the study means we will be able to monitor your training and response to training in a more detailed manner. Some of this information will be fed back to the strength & conditioning coaches who will be able to adjust your training or increase recovery if needed.

Confidentiality

All information which is collected about you during the course of the research will be kept strictly confidential between research staff and RGC staff. Some of the information including; morning heart rate variability, heart rate during training sessions, well-being and mood scores will have your names attached to the data so that it can be used by RGC staff to individually tailor your training load during pre-season. This information will be stored on WRU password protected laptops at Parc Eirias offices. Any information which leaves RGC will have your name and address removed so that you cannot be recognised from it. It will not be possible to identify you in any report or publication that may arise from the study and the data will only be stored for 5-years This data will include raw heart rate variability scores, demographic data including, your training and injury history, scores on psychological questionnaires and results of saliva biochemistry assays.

Who is organising or funding the research?

This research is organised by the named researchers from the School of Sport, Health and Exercise Sciences at Bangor University and supported by a grant from the Knowledge Economy Skills Scholarships (KESS 2) this is a major pan-Wales operation supported by European Social Funds (ESF) through the Welsh Government. KESS 2 grants links companies and organisations with academic expertise in the Higher Education sector in Wales to undertake collaborative research projects

Who has reviewed the study?

This study has been reviewed and approved by the Ethics Committee of School of Sport, Health and Exercise Sciences at Bangor University.

Feedback on Conduct of Research

SSHES is always keen to hear the views of research participants about their experience. If you would like to feedback, please ask the researcher to provide you with Form 6 – Participant Feedback Form – from the Ethics Guidelines Handbook. Completion of this form is optional. The completed form should be returned to Dr Anthony Blanchfield, Chair, Research Ethics Committee, SSHES, Bangor University, Bangor LL57 2PZ. All information will be treated in a strictly confidential manner.

You are also welcome to contact the University's assigned data protection officer (DPO) if for any reason you wish to. The DPO of Bangor University can be contacted on these details: Mrs Gwenan Hine: gwenan.hine@bangor.ac.uk; 01248 382413

Any Questions?

Please ask us if you have any questions. You should not sign the form consenting to take part in the study if you still have unanswered questions or any doubts.

Names, addresses, email and contact phone numbers of the researchers must be clearly displayed.

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List of online psychology questionnaires

- Historical training and injury data
- Athlete Burnout Questionnaire (Gustafsson et al., 2016)
- Multiple Assessment of Interoceptive Awareness (Mehling et al., 2012)
- Self-determination - Behaviour Regulation in Sport
- Toronto Alexithymia Scale
- Perfectionism
- Perceived Stress Scale
- Modified version of the Self Esteem Scale (performance subscale)
- Commitment to Training
- Motivation
- Goal orientation
- Optimism from LOTR
- The Big Five.

Thank you very much for taking the time to read this information sheet.

Bangor University

SCHOOL OF SPORT, HEALTH AND EXERCISE SCIENCES

1	Title of project	Athlete monitoring to help predict injury, illness and underperformance in rugby union players.
2	Name and e-mail address(es) of all researcher(s)	Mr Davide Mondin – d23mondin@gmail.com Mr Reece Smith - peu6cf@bangor.ac.uk Dr Julian Owen - j.owen@bangor.ac.uk Mr Gareth Whittaker – Gwhittaker@wru.wales

Please tick boxes

1 I confirm that I have read and understand the Information Sheet dated …………………. for the above study. I have had the opportunity to consider the information, ask questions and have had these answered satisfactorily.

2 (i) Patients:

I understand that my participation is voluntary and that I am free to withdraw at any time without giving a reason, without my medical care or legal rights being affected.

(ii) Students:

I understand that my participation is voluntary and that I am free to withdraw at any time without giving a reason. If I do decide to withdraw I understand that it will have no influence on the marks I receive, the outcome of my period of study, or my standing with my supervisor or with other staff members of the School.

(iii) General members of the public:

I understand that my participation is voluntary and that I am free to withdraw at any time without giving a reason.

3 I understand that I may register any complaint I might have about this experiment with Professor Tim Woodman, Head of School of Sport, Health and Exercise Sciences, and that I will be offered the opportunity of providing feedback on the experiment using the standard report forms.

4 I agree to take part in the above study.

Name of Participant ……………………………………………………………….

Signature …………………………………. Date …………………………………..

Name of Person taking consent…………………………………………………….

Signature …………………………………. Date …………………………………..

FULL METHODOLOGICAL RESEARCH PROTOCOL

PRIFYSGOL BANGOR UNIVERSITY

School of Sport, Health and Exercise Sciences
Bangor University,
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Bangor,
Gwynedd, LL57 2PZ

Title of study: Athlete monitoring to help predict injury, illness and underperformance in rugby union players.

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BACKGROUND

A comprehensive athlete monitoring system is crucial to understanding an athlete's individual responses to training and to prevent a potential shift in physical and psychological well-being towards over-reaching or burnout. Traditionally, research based on athletic populations have examined numerous contributing factors or “markers” of poor performance and ill health (e.g. physiological, hormonal, immune, performance, psychological and subjective measures). Despite this work there is yet to be a single, definitive marker described in the literature. A stronger research paradigm places an emphasis on monitoring multiple markers in a within-subject, individualised and longitudinal manner, enabling a better understanding of how fluctuations in markers predict the progression towards negative health outcomes and associated poor performance. In addition, to date over-reaching and burnout oriented research has been firmly grounded in either a physiological or psychological paradigm; there has been no systematic attempt to integrate both perspectives. Such research has likely been hampered by an inability to appropriately analyse data sets involving relatively few but closely monitored participants. However, innovative techniques such as pattern recognition analyses, may provide an alternative statistical approach to this problem.

Aim: to develop a systems-approach to athlete monitoring within the senior and academy rugby union squads at Rygbi Gogledd Cymru (RGC). The specific goals of the project is to complete longitudinal monitoring of RGC rugby players using multiple psychological and physiological markers, to identify markers or combinations of markers which can predict and underpin impending under-performance, illness, and injury.

METHODOLOGY

Location and timing of research.

All exercise tests will take place at the RGC training base at Eirias Park, Colwyn Bay. Study duration will be from 28th June 2018 to the end of September 2018.

Population to be studied and method of recruitment.

Professional and semi-professional senior and academy rugby union players (Under 18 and Under 16 squads; age range 15-18) representing the North Wales region for RGC. Potential participants will be recruited via player (senior team) and parent and player (academy team) information presentations.

Study Design and Flow.

For the intital part of this 12-month project, we aim to monitor multiple psychological and physiological markers related to training, performance and well-being in athletes over an 8-week intensified period of training during pre-season. This will involve an initial assessment of of historical information, training and competition behaviour and personality traits via online questionnaire. During the pre-season period the training load for each training session and match will be quantified, via a session RPE (sRPE) and by monitoring heart rate. In addition, measures of mood, well-being, first morning heart rate variability, heart rate recovery and performance via counter movement jump and reactive strength index will be recorded four times per week (Monday, Wednesday, Friday and Saturday). In addition, measures of gastrointestinal (GI) distress and upper respiratory tract (URTI) symptoms will be measured weekly. At intermittent times during the 8-weeks pre-season period (see below for details)saliva samples will be collected for subsequent analysis of testosterone, cortisol,alpha-amylase and immunoglobulin A. and further online assessments psychological constructs will also be recorded (Senior squad, two time points - following the first microcycle (week 4 of pre-season) and at the end of the pre-season period; U18 squad, before and after the Regional Academy Games series DATES)

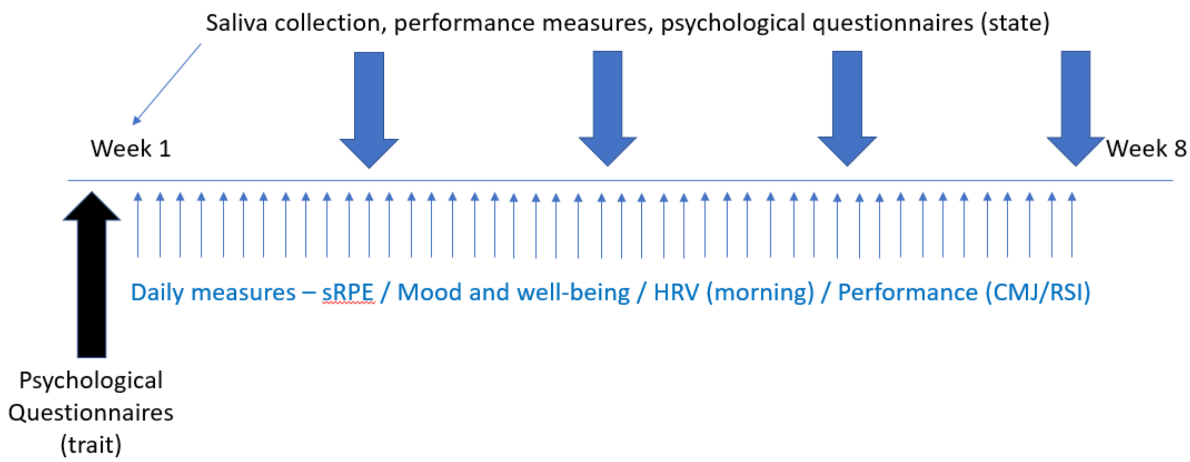

Figure 1. Schematic diagram of the study design during pre-season. Abbreviation: sRPE, session RPE; HRV, heart rate variability; CMJ, counter movement jump; RSI, reactive strength index.

Study Procedures.

A central factor in this research project will be to assess psychological and perceptual factors associated with athlete burnout (**Figure 2**; Gustafsson, Madigan, & Lundkvist, 2016), training related factors associated with an increased risk of injury i.e. acute to chronic workload ratio (Hulin, Gabbett, Lawson, Caputi, & Sampson, 2016) and other physiological markers known to be altered during over-reaching or underperformance syndrome e.g. performance indicators, indices of heart rate variability, heart rate recovery and hormonal and inflammatory markers (Holmberg et al., 2018).

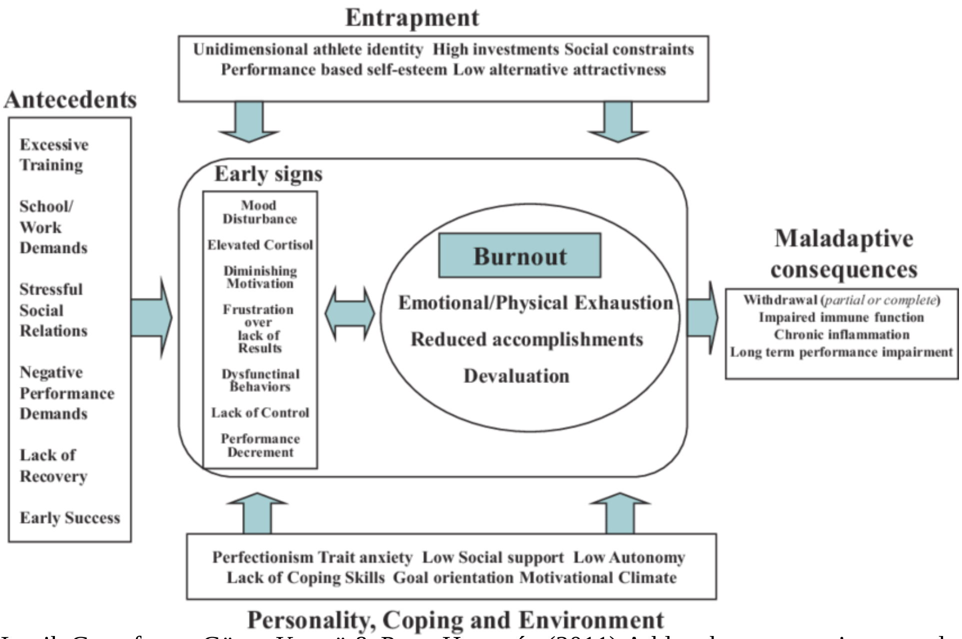

Figure 2. From Henrik Gustafsson, Göran Kenttä & Peter Hassmén (2011) Athlete burnout: an integrated model and future research directions, *International Review of Sport and Exercise Psychology*, **4**:1, 3–24.

<u>Initial baseline measures (week 0).</u>

Questionnaires

Before the start of the 8-week pre-season period players will receive a text message containing a a link to an online questionnaire pack to be completed by each player individually (*Qualtrics Research Core, Provo, US*). This pack will contain questions relating to information on training and injury history, as these factors have been found to be moderating factors in the training load-injury relationship (Gabbett, 2016). Further items from questionnaires assessing training and competition behaviours, personality, self-determination, burnout and interoception will also be recorded (**listed below and see attached appendices for further details**).

- Historical training and injury data
- Athlete Burnout Questionnaire (Gustafsson et al., 2016)
- Multiple Assessment of Interoceptive Awareness (Mehling et al., 2012)
- Self-determination - Behaviour Regulation in Sport
- Toronto Alexithymia Scale
- Perfectionism
- Perceived Stress Scale
- Modified version of the Self Esteem Scale (performance subscale)
- Commitment to Training
- Motivation
- Goal orientation
- Optimism from LOTR
- The Big Five.

Saliva sampling

On a pre-designated morning before the start of the pre-season period, unstimulated whole saliva samples will be collected on waking, using pre-weighed universal tubes (Sarstedt, Leics, UK). After thoroughly rinsing the mouth with water each subject will be asked to swallow in order to standardise the amount of residual saliva prior to collection. The subjects will be instructed to sit in an upright position with head tilted forwards slightly and to allow saliva to drain out between parted lips into the universal tube for 5 min with minimal ora-facial movements. Saliva volume will be estimated by weighing the universal tube immediately after collection to the nearest milligram, and saliva density will be assumed to be 1.00 g.ml-1. From this, the saliva flow rate will be determined by dividing the volume of saliva by the collection time. Saliva will then aspirated into eppendorfs and stored at -80 °C for further analysis. At the time of analysis, frozen saliva samples will be defrosted, centrifuged and analysed for concentrations of salivary testosterone, cortisol, immunoglobulin A and alpha-amylaseusing commercially available ELISA kits. In addition to measurement of sIgA concentration, salivary secretion rate for all analytes will be calculated by multiplying saliva flow rate by the saliva concentration.

Heart rate variability

After collecting saliva on waking, individual players will attach a Bluetooth heart rate monitor chest strap (Polar Electro H10, Kempele, Finland). After 5-min of seated rest, beat-to-beat heart rate will be recorded continuously for 5-min. All R–R series will be recorded via a mobile application and stored via web-based software (Team Dashboard, Elite-HRV, Texas, US). This will then be exported and text files analyzed in the time and frequency-domain after automated removal of occasional ectopic beats (Kubios, BSAMIG, Kuopio, Finland).

Measures of training response and mood

On the first morning of pre-season, players will receive a text message containing a link to a Google Docs form which will allow them to complete measures of well-being on a 5-point Likert scale, including; fatigue, sleep quality, general muscle soreness, stress levels and general mood, as described previously (McLean, Coutts, Kelly, McGuigan, & Cormack, 2010). In addition, players will also complete a more specific assessment of mood via the Brief Assessment of Mood (BAM; Shearer et al., 2015). BAM is a six-item scale that simply asks participants to rate their mood based on the six factors of the profile of mood states (POMS; i.e., anger, tension, depression, vigor, fatigue, and confusion). The BAM correlates well with the full versions of the POMS (Leunes & Burger, 2000), indicating that it holds a degree on concurrent validity with the original measure.

Anthropometric characteristics and fitness tests.

On the first day of pre-season, anthropometric measures of height and nude body mass (BM) will be assessed. In addition, on the first three-days of the pre-season period aerobic fitness will be estimated via the 30-15 test (see below for details), strength via a 1 repetition maximum (1-RM) bench press, squat, deadlift and clean and jerk; speed and acceleration via a 10 and 40 m sprint test and power and reactive strength index (RSI) measured via a countermovement jump and drop jump using a contact mat (Just Jump, Perform Better, UK), during these tests the speed of each jump will also be measured using an acceleromter attached to the waist (Band 2.0, PUSH Inc, US). Countermovement jump testing has been shown to be a valid and reliable test of explosive power (Markovic, Izdar, & Ukic, 2004) and has been recommended as a useful tool to measure neuromuscular training response in male team sport players (Twist & Highton, 2013). The RSI was developed to measure how an athlete copes and performs during plyometric activities by measuring the muscle-tendon stress and their reactive jump capacity. It demonstrates an athlete's ability to rapidly change from an eccentric motion into a concentric muscular contraction and is an expression of their dynamic explosive vertical jump capacity. The test has been shown to be a valid and reliable test in athletes and regularly used in the athlete monitoring context (Flanagan, Ebben, & Jensen, 2008).

<u>30-15 test</u> - consists of 30-second shuttle runs interspersed with 15-second walking recovery periods. The test starting speed is 8 km/h (i.e. first 30-second shuttle run), and this speed increases by 0.5 km/h for every 30-second stage thereafter. So, the running speed at stage 1 is 8km/h, stage 2 is 8.5km/h, stage 3 at 9km/h and so on. Athletes are required to run back and forth between the two lines set 40-metres apart at a speed governed by an audio "beep". As the individual progresses through the levels, the time between the beeps decreases giving the individual less time to complete each shuttle, thus increasing the speed/intensity of the test. The two 3-metre zones in the middle of the testing area (6-metres in total) exists so that the athletes can gauge the required running speed, and therefore adjust their speed accordingly (i.e. speed-up or slow-down). The two 3-metre end zones/turning lines also help guide the athlete to adjust/maintain their speed. During the 15-second recovery period, athletes are required to walk in a forward direction towards the closest 3-metre zone; this zone is where they will start the next running stage from. Athletes must reach the next 3-metre zone – either the middle one or the end zones – on a consistent basis. Failure to reach the next 3-metre zone on three consecutive occasions results in elimination from the test. Maximal aerobic power will then be estimated with the following equation:

VO_{2max} (ml.kg–1.min–1) = 28.3 – (2.15 x G) – (0.741 x A) – (0.0357 x W) + (0.0586 x A x VIFT) + (1.03 x VIFT)

Where: VIFT is the final running speed

G refers to gender (male = 1; female = 2)

A for age (in years)

W for weight (in kilograms)

<u>Daily measures during pre-season (week 1-8).</u>

During the pre-season period the following measures will be assessed on 4-days during the week (Monday, Wednesday, Friday and Saturday), mood, well-being and heart rate variability on waking in the morning, using the same protocols as outlined in the previous section. Internal training load will be measured during each training session and match using heart rate telemetry (Activio Sport System, Massachusetts, US) and 1-hour following each training session or match (approximately 4 days per week to include all training sessions and matches) using the session RPE method, which will be reported via a Google Docs application. This involves rating the intensity of the session on a Borg CR10 scale, then multiplying this figure by the duration of the session. This has been shown to be a valid and reliable measure of internal training load in intermittent team sports, and notably, applicable across multiple training modalities (Impellizzeri, Rampinini, Coutts, Sassi, & Marcora, 2004). In addition to these measures, countermovement jump and reactive strength index will be measured at the beginning of each training session other measures will be recorded once per week (Friday) at the beginning of the training session., as described in the previous section.

<u>Intermittent measures during pre-season (week 2, 4, 6 and 8)</u>

On weeks 2, 4, 6 and 8 during pre-season, additional psychological measures will be collected via online questionnaire (*Qualtrics Research Core, Provo, US*). These will include:

- Athlete Burnout Questionnaire (Gustafsson et al., 2016)
- Multiple Assessment of Interoceptive Awareness (Mehling et al., 2012)
- Self-determination - Behaviour Regulation in Sport
- Perceived Stress Scale

In addition, first morning saliva samples will be collected as described above, and stored at 80^{o}C at the laboratories of the School of Sport, Health and Exercise Sciences, Bangor University before further analysis of testosterone, cortisol and inflammatory markers.

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